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SALINE WATER CONVERSION

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HEARINGS
BEFORE THE
SUBCOMMITTEE ON IRRIGATION AND
RECLAMATION
OF THE
COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE
EIGHTY-NINTH CONGRESS
FIRST SESSION
ON

S. 24

A BILL TO EXPAND, EXTEND, AND ACCELERATE THE SALINE
WATER CONVERSION PROGRAM CONDUCTED BY THE SECRE-
TARY OF THE INTERIOR, AND FOR OTHER PURPOSES

MAY 18 AND 19, 1965

Printed for the use of the
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SALINE WATER CONVERSION

TUESDAY, MAY 18, 1965

U.S. SENATE,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION,
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 3110, New Senate Office Building, Senator Clinton P. Anderson presiding.

Present: Senators Jackson (chairman of the full committee), Anderson (chairman of the subcommittee), Moss, Burdick, and Allott.

Also present: Jerry T. Verkler, staff director; Theodore M. Schad, consultant, and Richard N. Little, minority counsel.

Senator ANDERSON. I think, in the interest of time, I am going to put my statement into the record as if read.

I am personally pleased to see the fine response to the call for hearings on the important subject before us this morning. We have a list of distinguished witnesses who, I am sure, will make a great contribution to the knowledge of the Senate and particularly of this committee.

One aspect about future desalting hearings should be mentioned at this time. Chairman Jackson of the full committee has announced his intention to schedule annual hearings hereafter on the "state of the art of desalination." The hearings might be carried out in a fashion similar to those on atomic energy developments and innovations that were held under section 202 of the Atomic Energy Act. I am sure this will be a significant contribution toward keeping our Government and our people aware of the tremendous importance of the desalination program, and I commend Chairman Jackson for his decision.

The Subcommittee on Irrigation and Reclamation of the Senate Committee on Interior and Insular Affairs opens its hearings this morning with a twofold purpose in mind: (1) To review the progress in saline water conversion under the expanded authorization provided by Public Law 87-295 which was approved by this committee in 1961, and which authorization expires in fiscal year 1967; and (2) to try to assess where we may be heading in this proposed \$275 million, 5-year program to advance desalting technology.

On March 29, the President again expressed his personal interests in desalting progress by sending a letter to the President of the Senate and to the Speaker of the House, in which he requested that a major acceleration in advanced desalting technology be authorized in this session of Congress. Legislation to accomplish this acceleration is before the committee in the form of S. 24, a bill to expand, extend, and

accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes. Without objection, a copy of the bill, S. 24, and a copy of the President's letter to the President of the Senate and the Speaker of the House will appear in the record following my comments.

At the present time we may well be at the crossroads of decision as to our future course in our desalination program. I am confident that some of our witnesses during these hearings will be able to give us sound and knowledgeable suggestions and advice. The desalting research program was initiated in 1952 under the first Saline Water Act, which was approved on July 3, 1952. The initial authorization provided \$2 million over a 5-year period. In 1955, the authorization was increased to \$10 million and the life of the program was extended to 1963. Five demonstration plants were authorized for construction by the act of September 2, 1958. The present level of the program was not achieved until the Anderson-Aspinall Act of 1961, which authorized \$75 million for the years 1962 to 1967, inclusive. Since that time, research and development expenditures have averaged about \$10 million annually, and a substantial increase is proposed in the 1966 budget.

The five demonstration plants have been constructed at San Diego, Calif. (this one was moved successfully to Guantanamo Bay during the United States-Cuban water crisis there); Webster, S. Dak.; Roswell, N. Mex.; Freeport, Tex.; and Wrightsville Beach, N.C. These plants appear to be operating in a range of performance from satisfactory and fulfilling-all-expectations, to poor and vexatious. In addition to the operational plants, a very substantial and necessary basic research program has been carried forward with the hope of finding either a new process for producing low-cost desalted water or a radical improvement of one or more known processes.

The Office of Saline Water in the Department of the Interior has pursued its solutions to economical desalting through attacking two separate problems simultaneously: (1) to find a way to supply the water needs of large coastal metropolitan areas where conventional sweet water is in short supply; and (2) to develop a process for improving the quality and usability of brackish and mineral-charged waters for inland communities at prices that people and industry can afford to pay.

These goals will presumably remain much the same as they have been, because these are the areas in need of the products of successful and economical desalting. But the routes by which they may be attained may perhaps be somewhat altered. The dual-purpose plants now under consideration appear to offer excellent cost-cutting opportunities, because whether atomic energy or conventional energy sources should be used in them, the end product is twofold, electric power generation and distillation. Their "scaled up" size promises economy as well, if the experience of the electric utility industry applies in this area.

(The bill and the message from the President follow:)

[S. 24, 89th Cong. 1st sess.]

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words " , module, component," after the word "laboratory."

(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,000,000" and the figure "1972" for the figure "1967".

THE WHITE HOUSE,
Washington, March 29, 1965.

HON. HUBERT H. HUMPHREY,
President of the Senate,
Washington, D.C.

DEAR MR. PRESIDENT. Past generations of Americans have been blessed with an abundance of sparkling, clean water. But in recent years we have become careless in our stewardship of this vital resource—polluting, wasting, and carelessly exploiting it.

Water shortages—real as well as prospective—already plague some regions of our land. Other areas and communities will soon be threatened. Yet, we must have an abundance of fresh water if we are to continue to grow and prosper.

Action to conserve what nature has so generously provided has often been inadequate and too late. We are determined not to make this mistake again. I have already pledged full support for cleaning up our rivers—and keeping them clean. We will continue to foster conservation by planning for the wisest possible use of all existing water supplies and by curbing and eliminating wasteful and uneconomic uses of water.

But these steps are not enough. New sources of supply at competitive costs are also required if we are to stay abreast of the ever-mounting demand for water. The seas around us offer an inexhaustible reservoir to help meet this need in coastal areas while vast quantities of brackish water are available to supplement the supplies of many inland areas. We must spare no effort in learning how to desalt these water economically.

For the past 12 years the United States has been engaged in a program of research and development which has brought desalting technology to a point where it shows promise of economic application in the future. To stimulate the translation of this promise into reality, I requested the Department of the Interior last July to develop, in close collaboration with the Atomic Energy Commission, a proposed program which would significantly advance large-scale desalting technology.

The resulting report entitled "Program for Advancing Desalting Technology" was completed promptly and released to the public on October 26, 1964. It recommended—and I am transmitting with this letter draft legislation to accomplish—expansion, extension, and acceleration of the salt water conversion research and development activities now being conducted by the Department of the Interior under authority of the Anderson-Aspinall Act of 1961.

This legislative proposal would increase by \$200 million the \$75 million appropriation authorization provided in the 1961 act and extend through 1972 the time during which the authorized funds would be available to support this important program. Enactment of this legislation is vital if the Department of the Interior is to mount and lead the substantial sustained effort necessary to achieve truly economical desalting of sea and brackish waters.

In the meantime, I have already transmitted to the Congress a request for a supplemental appropriation of \$3.9 million in 1965 to enable the Department, through a reorganized Office of Saline Water, to accelerate its research and development activities along the general lines outlined in the report mentioned above. Desalting activities will receive continuing emphasis in 1966. My budgetary recommendations to Congress for the coming fiscal year amount to

\$29 million for the Office of Saline Water, more than double the amount appropriated for 1965.

By pressing ahead with a vigorous program of economic desalting to meet our ever-growing domestic needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage. To stimulate cooperation in the field with such great potential for the good of mankind, the United States will convoke a symposium of interested nations in October 1965 to exchange information on desalting technology.

In recommending this measure to the Congress, I wish to acknowledge the foresight of such able legislators as Clinton Anderson, Wayne Aspinall, and the late Clair Engle. Our present efforts in desalting rest in substantial measure upon the sound foundation they laid and on which we intend to build. I earnestly hope that their leadership and the progress which it has inspired can be carried forward without interruption by the prompt enactment of the bill I am transmitting today.

Sincerely,

LYNDON B. JOHNSON.

Enclosure.

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

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(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,000,000" and the figure "1972" for the figure "1967".

Senator ANDERSON. Before proceeding with our first witness, who is the Secretary of the Interior, I would like to invite statements or comments from any member of the committee.

Mr. Secretary, we are always happy to welcome you here and happy to have you here at the hearing. We are pleased with your participation and progress in the desalination program. I, for one, have been happy for many years with it. You have made a great contribution to what America can be in the future. We thank you for the attitude you have taken on the desalination program.

STATEMENT OF HON. STEWART L. UDALL, SECRETARY, DEPARTMENT OF THE INTERIOR

Mr. UDALL. I am pleased to be here to discuss the program to advance desalting technology. I would like to summarize part of my statement and read part of it, Mr. Chairman.

Mr. Chairman, we are entering into what I think is probably the most critical phase of this program and I would like to say, first of all, that we appreciate the strong support we have received from this committee and particularly from the two gentlemen who are now present at this committee hearing. This program was initiated by the Congress and not the executive branch of the Government. The interest and support of the chairman of the subcommittee who is presiding, and

the chairman of the full committee, has been very vital throughout the life of the program.

I would like to say one other thing on a personal level and that is that the new director of our program, Mr. Di Luzio, who I borrowed from Senator Anderson, and I hope I borrowed him permanently, has proven to be what I had hoped he would be—a very competent director in a very complex and fast-moving program. He is here today and he can speak for himself. His virtues will be obvious, I am sure. Senator Anderson was fully aware of my actions when I persuaded Mr. Di Luzio to accept our offer to join the Department of the Interior. He has turned in an outstanding performance during his first 3 or 4 months and we have the greatest confidence in his ability.

Senator ANDERSON. Mr. Secretary, it was like asking a man to cut his own throat when you asked me to release him. I do think this is a great program of real importance and I appreciate the fact you have confidence in him.

Mr. UDALL. Up to this point, Mr. Chairman, that confidence has certainly been well placed.

Senator ANDERSON. I want to concur in that.

Senator JACKSON. I think the Secretary is very fortunate in having Mr. Di Luzio and the Secretary deserves great credit for the vigor in which he is pushing this program and the wisdom that he has exercised in getting good people to support him.

Mr. UDALL. Well, this is most vital as you know, and I think also the relationship that we have developed in the last 2 years with the AEC has been a very fruitful one. I think having the competence and the insight of two agencies or departments has given us new strength.

I am going to read part of my statement, starting at the top of page 6.

Senator ANDERSON. When you conclude your remarks, your statement will be placed in full in the record.

Mr. UDALL. Mr. Chairman, the desalting program was launched in 1952, with the passage of the Saline Water Act.

The initial authorization provided \$2 million over a 5-year period. This authorization was increased in 1955 and not less than five demonstration plants were authorized in 1958. However, the program did not reach its present level until the Anderson-Aspinall Act was enacted in 1961. Since that time, research and development expenditures have averaged \$10 million annually.

We are directing our efforts to the solution of two separate problems simultaneously. A way must be found to supply the water needs of large metropolitan areas near the coast where conventional water is in short supply.

Equally important, we need to develop a process that will improve the quality of brackish and minerally charged waters for inland communities at prices that will make this improvement economically feasible.

The Anderson-Aspinall Act enables us to establish substantial basic research programs to unearth knowledge that will hopefully lead to truly low-cost water through the discovery of new processes or the radical improvement of known processes.

Today, I would like to review these activities and discuss separately the plants that have been constructed under our demonstration and pilot plant programs.

The enactment of the Anderson-Aspinall Act in 1961 initiated an intensive program of basic research in the Office of Saline Water. Through basic research, we are increasing the storehouse of fundamental scientific information in areas relevant to desalting. The probabilities are that this research will pay off handsomely. Much of what we are learning may never be applicable to desalting, but may well find practical application in other related efforts.

In fact, some of it may have no practical application whatsoever. That risk is inherent in all research programs. Just establishing that an apparently attractive idea will not work adds to our total knowledge.

The engineering development program has been expedited by the establishment of a research and development test station at Wrightsville Beach, N.C. This installation provides a facility where the testing and development of processes, particularly at the pilot plant level, can be conducted under standardized conditions.

We have here at Wrightsville Beach a facility where Office of Saline Water contractors can conduct experimental work with administrative services and all utility services available; that is, sea water, fresh water, steam, electricity, compressed air, fuel storage, waste disposal, and reinforced concrete foundations for erection of pilot equipment or plants. At the present time, there are five pilot plants in operation and the sixth is nearing completion.

The Department was authorized under Public Law 85-883 of 1958 to construct not less than five demonstration plants to be located in five different areas and utilizing the five most advanced and promising processes.

As these plants have become operative, they have provided valuable opportunities for testing new ideas and modification under actual operating conditions. In 1959 and 1960, the following processes and locations were selected for these plants:

	<i>Gallons a day</i>
Multi-effect distillation—Freeport, Tex.....	1,000, 000
Flash distillation—San Diego, Calif.....	1, 000, 000
Electrodialysis—Webster, S. Dak.....	250, 000
Vapor compression distillation—Roswell, N. Mex.....	1, 000, 000
Freezing process—Wrightsville Beach, N.C.....	200, 000

The first of these plants at Freeport, Tex., using the multi-effect, long-tube distillation process, was completed in May 1961. Almost 1 billion gallons of water have been produced for the plant's customers during the past 3½ years.

In the course of its operation, many components have been replaced and other modifications have been made to improve the plant's operation. With these modifications in place, the plant is now producing its rated capacity of 1 million gallons per day, using only two-thirds of the heat exchange equipment. Additional modifications have been planned which we believe will further improve the process.

The multistage flash demonstration plant at San Diego, Calif., operated successfully for almost 2 years prior to its transfer last February to Guantanamo to meet the Navy's emergency need. By using the pH method of scale control at San Diego, we were able to increase the plant's operating temperature from 190° to 250° F. As a result, the plant's output increased 40 percent to 1,400,000 gallons per day with only a slight increase in operating costs.

You can see the type of experimentation we have been undertaking with these demonstration plants.

A new plant has been designed to replace the San Diego plant. It combines the best features of the previous plant with those of the Freeport plant. We call it the multistage, multi-effect process.

The 250,000 gallons per day electrodialysis plant at Webster, S. Dak., has processed all of the water for the city since March 1962. This plant has achieved all reasonable expectations. It has been on stream about 90 percent of the time and now operates unattended from midnight to 7 a.m. We are confident that the process can be further improved.

The 1-million-gallon-per-day brackish water vapor compression distillation plant at Roswell, N. Mex., was completed in July 1963, but has not yet operated at its designed capacity or for any extended period of time.

Among other things, it has been plagued by process problems related to pretreatment of the feedwater to avoid scale formation on the heat transfer surfaces of the evaporators. The plant operates under a delicate chemical balance in which the calcium is removed from the incoming brackish water stream by means of ion exchange. There also have been mechanical problems with equipment components. Performance of the system has been improved, but further equipment changes will be necessary.

A freezing process was chosen for the fifth demonstration plant at Wrightsville Beach, N.C. When the construction bids were received and analyzed, it was obvious that the freezing process had not been developed to the point where a freezing process demonstration plant could be expected to provide reliable performance and economic information.

Accordingly, the freezing process demonstration plant was not built. In its place, a larger pilot plant, the east coast conversion plant was built at Wrightsville Beach. Construction of this facility, with a design capacity of 200,000 gallons per day was completed in July 1964. Mechanical difficulties, along with some design problems, have prevented successful operation and fresh water production.

In cooperation with the Department of State, we have arranged the First International Symposium on Water Desalination which will be held in Washington, D.C., on October 3-9, 1965. We have extended invitations to all countries with which the United States has diplomatic relations. Fifty-three nations have already indicated their intention to send official delegations to the meeting. Total attendance is expected to number some 700 to 900 individuals representing the world's outstanding talent in desalting research and engineering. This indicates the broad, international interest in this program and we predict and hope it will be a very outstanding conference and we are giving the planning a great deal of attention at all levels.

During the past year, we exchanged visits of delegations on desalting with the U.S.S.R. and in November, our countries entered into an agreement to cooperate in desalination, including the use of nuclear energy for that purpose. To date, no formal actions have been taken under this agreement, but we anticipate that the first step will be an exchange on a reciprocal basis of technical experts who will make detailed inspections of work that is of special interest to each country.

The Soviet Union seems to be sponsoring a rather comprehensive desalting program. The team of experts who visited Russia did not have time for a full study of the Soviet effort, but they reported significant engineering accomplishments. They are operating a plant of 1.5 million gallons per day which serves as the sole source of water supply for the 20,000 people of the city of Schevchenko that is being built on the Caspian Sea.

They plan to build a nuclear-powered dual-purpose plant at this same location; in fact, the reactor is already under construction. The initial visit to the Soviet Union convinced our representatives that we could benefit substantially from an exchange of technical information.

Large, dual-purpose plants, using a common source of energy for electric power generation and distillation, offer opportunities for reducing the cost of the product water. These economies result from more efficient use of energy completely independent of opportunities which may exist for assigning costs so as to reduce the price of one product or the other.

Preliminary indications of the economies obtainable in large size, dual-purpose plants have been set forth in studies prepared for the Office of Saline Water, as well as in the report on "Large Nuclear-Powered Sea Water Distillation Plants," sponsored by the President's Office of Science and Technology.

More importantly, two major water supply agencies—the Metropolitan Water District of Southern California and the Government of Israel—are seriously considering the construction of large, dual-purpose desalting and electric powerplants.

On August 18, 1964, the Department entered into a contract with Metropolitan, the largest in the United States, to undertake an engineering and economic feasibility study of a plant within the ranges of 50 to 150 million gallons per day and 150 to 750 megawatts electric. Metropolitan would like to have this plant in service by 1970. The study, financed jointly by Interior, the Atomic Energy Commission, and Metropolitan, is being made by the Bechtel Corp. and is scheduled for completion in October. It is moving ahead right to schedule.

As in the case of the Metropolitan Water District, the Department and the Atomic Energy Commission are sharing with the Government of Israel the cost of a feasibility study for a large dual-purpose plant being considered for construction by 1971. This study is being undertaken by Kaiser engineers and is expected to be completed this fall.

Should the project prove to be economically attractive, the engineer's report will form the basis for appropriate decisions regarding further action.

Having noted participation of the Atomic Energy Commission in the two feasibility studies, I would like to digress for a moment to clarify the Department's relationship with the Commission. I would like to say it has been very harmonious and Dr. Seaborg and Commissioner Ramey and others of the AEC have had frequent consultations at the very highest level.

The Federal responsibility for the desalting program is lodged—and I trust always will be lodged—in the Department of Interior. Nuclear power, however, has an unique importance as a potential source of cheap energy for large-size plants. Consequently, we have

been working closely with the Atomic Energy Commission to coordinate our developed program.

We have one large research contract with the Atomic Energy Commission laboratories.

There is no magic to nuclear energy as such—a distillation plant will not work any better on steam generated by a nuclear source. The important factor is not the source of the steam, but its cost. This is, of course, when we look on down the road to what makes nuclear power particularly attractive.

In this regard, the Office of Saline Water has made arrangements with other agencies within Interior to keep abreast of developments in the technology of fossil fuels that will be applicable to desalting. It may be there will be some fossil fuel plants that will be most practicable.

The new program that has been devised to advance desalting technology will change the character of the program by placing greater emphasis on engineering problems and the development of hardware for prototype plants ranging up to 50 million gallons per day. With the expanded program we propose, we will be able to undertake this new and necessary work and at the same time maintain a balance between engineering and research.

The emphasis on engineering will enable us to rapidly utilize existing technology in plants of advanced design and research will provide the insurance policy for the future through which we will be able to foresee future lines of development, improve existing processes and develop entirely new approaches to solve the long-range problems of low-cost desalination.

In the formulation of a development program of this nature, which is undergoing a major transition from research and small plant engineering to a full-scale engineering program, it is impossible for us at this time to foresee the advances that will accrue from our activities.

We can be reasonably certain, however, that some of our engineering operations will reach a point where the information we acquire will need to be tested in prototype plants in order to accurately determine operating characteristics and economic parameters. We believe it would be inappropriate to attempt to make decisions concerning the need for legislation relating to the construction and field operation of plants based on the incomplete data presently available, particularly with these two large studies outstanding.

The only reasonable approach to this situation is to continue our examination of the President's program and then make our decisions when we can clearly identify the requirement for a plant or plants that show great promise of carrying out the mandate of the Congress. This approach will also enable us to locate these plants where the fresh water they produce can be utilized by a city or a community.

We have clearly identified the need of developing a new position to participate more fully with other Government agencies as we explore the potential utilization of desalination processes to combat pollution and acid mine water problems.

President Johnson has stated on a number of occasions that it is his intention to share desalting technology with other nations. That is one of the reasons for the conference this fall.

To carry out the wishes of the President we will have to engage in greater participation in engineering and feasibility studies in foreign lands. Through a joint effort with the Department of State we may be able to assist the Department of State to further the administration's foreign policy goals through a contribution of services.

To be perfectly candid, I would be less than honest if I told this committee that S. 24 as submitted contains all the authority we may require to reach our objectives. As the program unfolds we may see the need for additional legislation in order to meet unanticipated problems or take advantage of new developments.

In closing, I would like to summarize by saying that the steady progress that has been made during the first 12 years of the desalting program has laid a firm foundation for the program which President Johnson is now proposing.

The program has received a fine response from industry and the research community.

I would like to comment here that I think the response and performance of our research contracts and plant contract has been almost uniformly outstanding.

On the horizon we can now see the possibility that this technology will economically serve the water needs of a number of areas both at home and around the world. With your assistance and guidance, we will do everything within our capabilities to realize that objective in a timely fashion.

Mr. Chairman, I would like to close simply by saying that I feel we have a strong team in operation. Director Di Luzio has recently revised his organization and added a few new people with new competence to the Office of Saline Water. I feel that there are big things in the offing and with the continued support of this committee and the continued support of the Appropriations Committee for the funds we will need, we can achieve the goals that have been put before us by this committee.

Senator ANDERSON. Mr. Secretary, I want to compliment you on a very fine statement as well as a very fine attitude.

On page 12 you refer to the contracts you are entering into with the Metropolitan Water District of Los Angeles. I think the first published document on the use of nuclear energy on the desalination of water was an AEC publication in 1955, a paper written by Phillip Hammond, who was then an obscure worker at Los Alamos but who did understand there was a desire to go along in that direction. He pointed out what it would take to get potable water down to a reasonable cost in a plant of this size. Of course, he predicted at that time there was no possibility of building that sort of plant for many years.

At that time, some of us, in discussing it, thought it would be 20 years and I am happy you have the time cut in half. The study is going on and being very well handled.

Then, on page 13 you refer to the fine relations you have with the Atomic Energy Commission. As you know, some of those people connected with the Commission are longtime associates of Senator Jackson and myself on the Joint Committee on Atomic Energy and I can assure you from conversations with them that they are as pleased with your cooperation as you are with theirs.

I have questions I would like to ask that might better be directed to Mr. Di Luzio at the close of the hearing. I want to congratulate you

on the start you are making, on the dedication of your whole team, and the personal leadership you have given to it.

Senator JACKSON. I merely want to associate myself with the remarks of the chairman of the subcommittee. I think the relationship with the AEC is an excellent one. It is obvious that the two great agencies have to work hand in hand with the primary responsibility in the Interior Department. I am delighted this relationship is working so well.

Senator Anderson and I, knowing the Commission and the Department of the Interior, are not at all surprised.

Senator ANDERSON. Senator Moss?

Senator MOSS. Thank you, Mr. Chairman. This is a fine progress report and I appreciate the distance we have come already and the prediction of acceleration in this research field and I look forward to hearing the additional witnesses we are going to have.

Senator ANDERSON. Senator Burdick?

Senator BURDICK. No questions.

Senator ANDERSON. Senator Allott?

Senator ALLOTT. No questions.

Senator ANDERSON. Thank you very much, Mr. Secretary. I appreciate your being here.

(The prepared statement of Secretary Udall follows:)

STATEMENT OF HON. STEWART L. UDALL, SECRETARY, DEPARTMENT OF THE INTERIOR

Mr. Chairman, members of the committee, we appear before you today, primarily to review progress in desalting under the expanded authorization provided by Public Law 87-295 which was approved by this committee in 1961. As you know, President Johnson has maintained a longtime personal interest in the desalting program. At his request, we have developed the accelerated program to advance desalting technology which we will describe in detail to the committee at this hearing.

Before beginning this report, I would like to introduce to those members who do not already know him, Frank C. Di Luzio, our new Director of the Office of Saline Water. We are pleased that we have secured a man of Frank's ability to direct this program. He is both an engineer and a proven administrator. He brings to the Department's desalting program an invaluable background in guiding research in nuclear and space technology. He comes to us from the Senate Committee on Aeronautical and Space Sciences, where he served as staff director. I will review program developments to date and Frank will go into the details of the new program.

As the program of the Office of Saline Water has developed over the past dozen years, many strands of data have been woven together to form a web of information. The sum of technical information that has been acquired is reflected in a series of studies and reports of a number of committees and organizations.

The 1961 Report of the Senate Select Committee on National Water Resources states: "The importance of Government policy in meeting the water resources problems ahead cannot be denied. The recommendations which follow are based on the committee's belief that future demands can be met best by finding the proper combination of (a) construction program; (b) scientific research; (c) development of known technical methods; and (d) strengthening of Government policies affecting water development and use. Such a combination of efforts cannot be achieved overnight, and will require the combined efforts of the legislative and executive branches of the Federal Government, as well as a continuation and strengthening of work in these fields of State and local governments and private enterprise."

All of the foregoing combination listed by the committee to meet future water demands are directly applicable and are being utilized in the saline water program, but even more important is the successful working partnership the Office of Saline Water has formed with private industry to advance desalting technology.

The select committee recommended: "Expanding the programs of basic research dealing with atmospheric physics, solar activity, hydrology of ground water movement and recharge, the physical chemistry and molecular structure of water, photosynthesis, and other natural phenomena associated with water in all its forms. Such research is essential to a major breakthrough in such fields as short- and long-range weather forecasting, weather modification, efficient management of underground reservoirs, evaporation reduction, desalinization, and pollution abatement, as well as to major improvements in works for the storage and control of water."

To name some of the additional reports without attempting to extract information from each, there was the 1961 report "Research Needs for Salt Water Conversion," a staff study of the Committee on Science and Astronautics of the House of Representatives; "Desalination Research and the Water Problem," a report of a month-long research conference convened by the National Academy of Sciences-National Research Council in 1961; the comprehensive report by the Task Group on Coordinated Water Resources Research "Federal Water Resources Research Activities" in 1963; the United Nations report "Water Desalination in Developing Countries"; and the Office of Science and Technology's "An Assessment of Large Nuclear Powered Sea Water Distillation Plants." All of these reports and others reach the same general conclusion: There is a need to expand at the Federal level and develop programs that will make additional water available to meet our growing demands for this vital commodity.

President Johnson has demonstrated over the years his interest in the saline water conversion program. He introduced legislation while still a Senator which called for an expanded saline water program. In an article he wrote for publication in the New York Times while Vice President, he stated: "There is no newer or more vital frontier for any of us than the one we must cross to a lasting abundance of fresh water for all mankind."

In the state of the Union message, the President said: "We must also recognize and encourage those who can be pathfinders for the Nation's imagination and understanding.

"To help promote and honor creative achievements, I will propose a National Foundation on the Arts.

"To develop knowledge which will enrich our lives and insure our progress, I will recommend programs to encourage basic science, particularly in the universities—and to bring closer the day when the oceans will supply our growing need for fresh water."

During the visit of the Prime Minister of Israel, last June, the President told Mr. Eshkol: "Today, Israel is a vital, prosperous land, a symbol of the courage and the strength of her people. The United States is proud to have assisted in this high enterprise. We are prepared to continue our contributions to technical advancement in Israel, particularly in the field of desalinization of water * * *."

These are but a few of the President's forthright statements which underscore his interest in advancing desalting technology.

We are not advocating a crash program for water desalting. We have developed what we consider to be a development time schedule geared to meet anticipated needs. There are some who say the general need for desalting processes throughout the United States is not urgent. I hasten to point out, however, that the nature of the desalting effort will require not only the development of technical information but also a considerable amount of data on resources on a regional basis. We have some good projections on water requirements, but it is virtually impossible to accurately predict when the need for desalting processes will become critical. That will be a function of time and economics.

We must use the time we now have available effectively and thereby avoid the need for a crash program which experience has shown can often require a foolish and wasteful expenditure of funds.

We believe in an orderly and planned program which will push the development of data through field testing and prototype operation in a hard-hitting and straightforward engineering program. By implementing this type of program, we can best carry forward President Johnson's expressed desires for an imaginative and aggressive desalting effort.

HISTORY OF THE SALINE WATER PROGRAM

The desalting program was launched in 1952, with the passage of the Saline Water Act. The initial authorization provided \$2 million over a 5-year period. This authorization was increased in 1955 and not less than five demonstration

plants were authorized in 1958. However, the program did not reach its present level until the Anderson-Aspinall Act was enacted in 1961. Since that time, research and development expenditures have averaged \$10 million annually.

We are directing our effort to the solution of two separate problems simultaneously. A way must be found to supply the water needs of large metropolitan areas near the coast where conventional water is in short supply. Equally important, we need to develop a process that will improve the quality of brackish and minerally charged waters for inland communities at prices that will make this improvement economically feasible. The Anderson-Aspinall Act enabled us to establish substantial basic research programs to unearth knowledge that will hopefully lead to truly low-cost water through the discovery of new processes or the radical improvement of known processes.

Today, I would like to review these activities and discuss separately the plants that have been constructed under our demonstration- and pilot-plant programs.

RESEARCH

The enactment of the Anderson-Aspinall Act of 1961 initiated an intensive program of basic research in the Office of Saline Water. Through basic research, we are increasing the storehouse of fundamental scientific information in areas relevant to desalting. The probabilities are that this research will pay off handsomely. Much of what we are learning may never be applicable to desalting, but may well find practical application in other related efforts. In fact, some of it may have no practical application whatsoever. That risk is inherent in all research programs. Just establishing that an apparently attractive idea will not work adds to our total knowledge.

PILOT PLANTS

The engineering development program has been expedited by the establishment of a research and development test station at Wrightsville Beach, N.C. This installation provides a facility where the testing and development of processes, particularly at the pilot-plant level, can be conducted under standardized conditions. We have at Wrightsville Beach a facility where Office of Saline Water contractors can conduct experimental work with administrative services and all utility services available; that is, sea water, fresh water, steam, electricity, compressed air, fuel storage, waste disposal, and reinforced concrete foundations for erection of pilot equipment or plants. At the present time, there are five pilot plants in operation and the sixth is nearing completion.

DEMONSTRATION PLANTS

The Department was authorized under Public Law 85-883 of 1958 to construct not less than five demonstration plants to be located in five different areas and utilizing the five most advanced and promising processes. As these plants have become operative, they have provided valuable opportunities for testing new ideas and modification under actual operating conditions. In 1959 and 1960, the following processes and locations were selected for these plants:

	<i>Gallons per day</i>
Multi-effect distillation, Freeport, Tex.....	1, 000, 000
Flash distillation, San Diego, Calif.....	1, 000, 000
Electrodialysis, Webster, S. Dak.....	250, 000
Vapor compression distillation, Roswell, N. Mex.....	1, 000, 000
Freezing, Wrightsville Beach, N.C.....	200, 000

The first of these plants at Freeport, Tex., using the multi-effect, long-tube distillation process, was completed in May 1961. Almost 1 billion gallons of water have been produced for the plant's customers during the past 3½ years. In the course of its operation, many components have been replaced and other modifications have been made to improve the plant's operation. With these modifications in place, the plant is now producing its rated capacity of 1 million gallons per day, using only two-thirds of the heat exchange equipment. Additional modifications have been planned which we believe will further improve the process.

The multistage flash demonstration plant at San Diego, Calif., operated successfully for almost 2 years prior to its transfer last February to Guantanamo to meet the Navy's emergency need. By using the pH method of scale control

at San Diego, we were able to increase the plant's operating temperature from 190° to 250° F. As a result, the plant's output increased 40 percent to 1,400,000 gallons per day with only a slight increase in operating costs.

A new plant has been designed to replace the San Diego plant. It combines the best features of the previous plant with those of the Freeport plant. We call it the multistage, multi-effect process.

The 250,000-gallon-per-day electrodialysis plant at Webster, S. Dak., has processed all of the water for the city since March 1962. This plant has achieved all reasonable expectations. It has been on stream about 90 percent of the time and now operates unattended from midnight to 7 a.m. We are confident that the process can be further improved.

The 1-million-gallon-per-day brackish water vapor compression distillation plant at Roswell, N. Mex., was completed in July 1963, but has not yet operated at its designed capacity or for any extended period of time. Among other things, it has been plagued by process problems related to pretreatment of the feed water to avoid scale formation on the heat transfer surfaces of the evaporators. The plant operates under a delicate chemical balance in which the calcium is removed from the incoming brackish water stream by means of ion exchange. There also have been mechanical problems with equipment components. Performance of the system has been improved, but further equipment changes will be necessary.

A freezing process was chosen for the fifth demonstration plant at Wrightsville Beach, N.C. When the bids had been received and analyzed, it was obvious that the freezing process had not been developed to the point where a freezing plant could be expected to provide reliable performance and economic information.

Accordingly, the freezing process demonstration plant was not built. In its place, a larger pilot plant, the East Coast Conversion Plant was built at Wrightsville Beach. Construction of this facility, with a design capacity of 200,000 gallons per day was completed in July 1964. Mechanical difficulties, along with some design problems have prevented successful operation and fresh water production.

INTERNATIONAL ASPECTS OF DESALTING

In cooperation with the Department of State, we have arranged the First International Symposium on Water Desalination which will be held in Washington, D.C., on October 3-9, 1965. We have extended invitations to all countries with which we have diplomatic relations. Forty nations have already indicated their intention to send official delegations to the meeting. Total attendance is expected to number some 700 to 900 individuals representing the world's outstanding talent in desalting research and engineering.

During the past year, we exchanged visits of delegations on desalting with the U.S.S.R. and in November our countries entered into an agreement to cooperate in desalination, including the use of nuclear energy for that purpose. To date, no formal actions have been taken under this agreement, but we anticipate that the first step will be an exchange on a reciprocal basis of technical experts who will make detailed inspections of work that is of special interest to each country. The Soviet Union seems to be sponsoring a rather comprehensive desalting program. The team of experts who visited Russia did not have time for a full study of the Soviet effort, but they reported significant engineering accomplishments. They are operating a plant of 1.5 million gallons per day which serves as the sole source of water supply for the 20,000 people of the city of Schevchenko that is being built on the Caspian Sea. They plan to build a nuclear-powered dual-purpose plant at this same location—in fact the reactor is already under construction. The initial visit to the Soviet Union convinced our representatives that we could benefit substantially from an exchange of technical information.

LARGE PLANTS

Large dual-purpose plants, using a common source of energy for electric power generation and distillation, offer opportunities for reducing the cost of the product water. These economies result from more efficient use of energy completely independent of opportunities which may exist for assigning costs so as to reduce the price of one product or the other.

Preliminary indications of the economies obtainable in large-size, dual-purpose plants have been set forth in studies prepared for the Office of Saline Water, as well as in the report on large nuclear-powered sea water distillation plants,

sponsored by the President's Office of Science and Technology. More importantly, two major water supply agencies—the Metropolitan Water District of Southern California and the Government of Israel—are seriously considering the construction of large dual-purpose desalting and electric powerplants.

On August 18, 1964, the Department entered into a contract with Metropolitan to undertake an engineering and economic feasibility study of a plant within the ranges of 50 to 150 million gallons per day and 150 to 750 megawatts electric. Metropolitan would like to have this plant in service by 1970. The study financed jointly by Interior, the Atomic Energy Commission, and Metropolitan, is being made by the Bechtel Corp., and is scheduled for completion in October.

As in the case of the Metropolitan Water District, the Department and the Atomic Energy Commission are sharing with the Government of Israel the cost of a feasibility study for a large dual-purpose plant being considered for construction by 1971. This study is being undertaken by Kaiser engineers and is expected to be completed this fall.

Should the project prove to be economically attractive, the engineer's report will form the basis for appropriate decisions regarding further action.

Having noted participation of the Atomic Energy Commission in the two feasibility studies, I would like to digress for a moment to clarify the Department's relationship with the Commission. The Federal responsibility for the desalting program is lodged—and I trust always will be lodged—in the Department of the Interior. Nuclear power, however, has a unique importance as a potential source of cheap energy for large-size plants. Consequently, we have been working closely with the Atomic Energy Commission to coordinate our development program.

There is no magic to nuclear energy as such—a distillation plant will not work any better on steam generated by a nuclear source—the important factor is not the source of the steam, but its cost. In this regard, the Office of Saline Water has made arrangements with other agencies within Interior to keep abreast of developments in the technology of fossil fuels that will be applicable to desalting.

The new program that has been devised to advance desalting technology will change the character of the program by placing greater emphasis on engineering problems and the development of hardware for prototype plants ranging up to 50 million gallons per day. With the expanded program we propose, we will be able to undertake this new and necessary work and at the same time maintain a balance between engineering and research. The emphasis on engineering will enable us to rapidly utilize existing technology in plants of advanced design and research will provide the insurance policy for the future through which we will be able to foresee future lines of development, improve existing processes, and develop entirely new approaches to solve the long-range problems of low-cost desalination.

In the formulation of a development program of this nature, which is undergoing a major transition from research and small plant engineering to a full-scale engineering program, it is impossible for us to foresee the advances that will accrue from our activities. We can be reasonably certain, however, that some of our engineering operations will reach a point where the information we acquire will need to be tested in prototype plants in order to accurately determine operating characteristics and economic parameters. We believe it would be inappropriate to attempt to make decisions concerning the need for legislation relating to the construction and field operation of plants based on the incomplete data presently available.

The only reasonable approach to this situation is to continue our examination of the President's program and then make our decisions when we can clearly identify the requirement for a plant or plants that show great promise of carrying out the mandate of the Congress. This approach will also enable us to locate these plants where the fresh water they produce can be utilized by a city or a community.

We have clearly identified the need of developing a new position to participate more fully with other Government agencies as we explore the potential utilization of desalination processes to combat pollution and acid mine water problems.

President Johnson has stated on a number of occasions that it is his intention to share desalting technology with other nations. To carry out the wishes of the President we will have to engage in greater participation in engineering and feasibility studies in foreign lands. Through a joint effort with the Department

of State we may be able to assist the Department of State to further the administration's foreign policy goals through a contribution of services.

To be perfectly candid, I would be less than honest if I told this committee that S. 24 as submitted contains all the authority we may require to reach our objectives. As the program unfolds we may see the need for additional legislation in order to meet unanticipated problems or take advantage of new developments.

In closing, I would like to summarize by saying that the steady progress that has been made during the first 12 years of the desalting program has laid a firm foundation for the program which President Johnson is now proposing. The program has received a fine response from industry and the research community. On the horizon we can now see the possibility that this technology will economically serve the water needs of a number of areas both at home and around the world. With your assistance and guidance, we will do everything within our capabilities to realize that objective in a timely fashion.

Senator ANDERSON. Mr. Simpson, we are happy to have you here. You go right ahead. I believe you have appeared before the Joint Committee on Atomic Energy a few times and I just did not recognize an old friend for a moment.

**STATEMENT OF JOHN W. SIMPSON, GROUP VICE PRESIDENT,
ELECTRIC UTILITY GROUP, WESTINGHOUSE ELECTRIC CORP.;
ACCOMPANIED BY ROY GAUNT, MANAGER, WATER PROJECT
DEPARTMENT, PHILADELPHIA, PA.**

Mr. SIMPSON. Thank you, Mr. Chairman.

My name is John W. Simpson and I am a group vice president of Westinghouse Electric. I have with me Mr. Roy Gaunt who is manager of our water projects department in Philadelphia.

I thank you for this opportunity to appear before the committee. Westinghouse is in complete accord with the objectives and in general accord with the approach of the Federal desalting program as set forth by the Secretary of the Interior and the Office of Saline Water. We believe that the President's request for a "vigorous program of economic desalting" deserves congressional support.

We have had a half century of interest and experience in the purification of water. This is because the boiler that supplies steam to a steam turbine must be fed ultrapure water.

Westinghouse began to purify brackish and mineral-charged water for electric powerplants in the early 1930's using submerged tube-type evaporators. By the middle of the 1930's our water evaporators were in common use by utilities and industrial plants throughout the country.

In 1948, we began to research, develop, and build the first large-scale plant for distilling ocean salt water. We did this for the Sheikdom of Kuwait on the Persian Gulf. Our plants in that area are now producing slightly more than 5 million gallons of pure water per day.

We have completed, are building, or have signed contracts to build flash evaporator desalting plants with a total daily capacity of nearly 14 million gallons. One of the completed plants was the OSW installation at Point Loma, Calif. This plant was supplying 1.4 million gallons of water per day to San Diego's water system before it was moved to Guantanamo Naval Base in Cuba. There we have added two

additional units to bring total daily water production at Guantanamo to $2\frac{1}{4}$ million gallons.

Most Americans who are at all knowledgeable on the subject agree and understand, I think, that certain of our communities have a serious shortage of water; that hundreds of other communities are now drinking water that falls considerably short of recommended purity levels; that with the rapidly growing need for water, the problem could become one of catastrophic proportions unless something is done; and that an important part of the problem will be solved if we can economically convert ocean salt water into potable water. They realize also, I believe, that what we do to help solve the worldwide problem of water resources will be a service to all mankind and a contribution to the image of America everywhere.

This leaves us with two basic questions to consider. First, what is the present and potential capability of American industry in the technology of water conversion? That is, can we convert sea water on a practical, economical basis? Second, what kind of water conversion program should we carry out?

As to the first question, speaking for Westinghouse, we consider that our technical capability is excellent. We can build plants that will purify ocean salt water. We know this because we are doing it.

From building the Point Loma plant and from the knowledge gained from our other installations, we know that there is no technical limitation on size. Now the time is right to move upward in size. It is technically feasible now to build desalting plants as large as anyone wants—50 million gallons a day, or 100 million gallons, or 150 million gallons, or larger—with life expectancy comparable to that of powerplants. The pioneering research work has been done. What remains to be done is a rigorous engineering effort, an effort to build ever larger plants to verify the point at which maximum advantage is gained from economics of size. Today's cost of about \$1 per thousand gallons in a 1-million-gallon-per-day plant could be reduced, we estimate, to from 30 to 35 cents in a plant of 50 million gallons per day capacity, based on like conditions. This would be water delivered at the water desalting plant boundary.

Thus the groundwork has been laid for an acceleration of the water conversion program as proposed by the President. This is a remarkable technical achievement, and all the more so because it has been done with a comparatively modest expenditure of Federal funds. Until a few years ago, of course, industry was conducting its research, development, and construction with its own money without Federal support.

When the Office of Saline Water began its program, it did so with a relatively small budget and an even smaller staff. Yet this small force, spending less than \$7 million for demonstration plant construction and working closely with private industry, initiated and managed a five-part prototype program of tremendous importance to the Nation.

This program has shown plainly that water can indeed be produced at far less than the \$4 per thousand gallons which once was considered a realistic price. And, more important, it has produced basic knowledge about various processes and has shown what areas need more research and what areas need engineering as the next step forward.

The question that faces the Nation now is the crucial one: What direction should the water conversion program now take? In Mr. Kenneth Holum's words:

We have reached a point in the Department's desalting program where important decisions must be made.

In the opinion of Westinghouse, the best and fastest progress to bring down costs in water desalting and in the foreseeable future will be made in multistage flash distillation units such as that used at Point Loma, Guantanamo Bay, and in many other installations.

We have been conducting research in other water conversion methods for some years, including reverse osmosis, freezing, and vapor compression. We also have investigated the electrodialysis process. We are pushing ahead with construction of multistage flash distillation plants because we have found that no other process presently approaches the technical feasibility and the overall economy of this method; because it is the one process that has proved itself in operation; because it is the only system that is now producing water in volume; because it is 2 to 5 years ahead of the other systems; because it lends itself to combination with power production; and because it is the only system that is sufficiently developed and ready today for large-scale plant construction with firm price, performance, and completion date guaranteed by the builder.

This process has the additional advantage of lending itself well to future modifications as new advances in technology occur. It will not be rendered obsolete, for example, as we learn how to increase operating temperatures above the maximums possible today—an advance which lies ahead and which will substantially reduce the capital cost of plant construction for a given water output.

We believe, secondly, that there is a great potential for large plants that produce both electricity and pure water. To desalt water you need heat. A powerplant rejects well over half of its heat input. By every evidence of experience, technology, and economics, these two plants complement each other and belong together. It makes sense to take the flow of turbine steam in its lower stages and divert it in whole or in part for the production of fresh water. It goes without saying that there must be a market for a large amount of both water and power.

For those areas of our country that lack resources of fossil fuel and need massive amounts of water and power, there can be great economic and technical advantages in marrying the large atomic powerplant and the large water desalting plant. We believe that, as this technology develops and the need increases, this is the direction that water desalting will follow in such areas.

One basic factor to consider here is that the atomic powerplant lends itself admirably to the economy of size. The equation is quite simple and definite: The larger the atomic powerplant requirement, the lower the unit production cost, whether measured in B.t.u.'s of heat, kilowatt-hours of electricity, or gallons of water.

On the other hand, there is a more moderate reduction in unit cost as the conventional powerplant increases in size. There appears to be almost no significant reduction as a result of increasing the size of installations that convert water by processes other than distillation.

The nuclear desalting plant can be a dual-purpose installation for

the production of electricity and water, or it can be a single-purpose plant for the production of water alone. But in either case, atomic power must pass the test of the marketplace, just as it is doing now in the powerplant field.

There is no magic correlation between a nuclear reactor and a flash evaporator—that is to say, a nuclear reactor is still the same heat source, whether it is hooked up to a steam turbine or an evaporator. The cost of desalting water is largely the cost of generating the heat, and the evaporator cares not at all where the heat comes from.

Naturally, the owner will want the heat to come from the fuel that is the most economical in his given region and circumstances: coal, oil, natural gas, or nuclear.

As a veteran in the atomic power business, I must add that I see no reason to think that the light water reactor will be supplanted as the most satisfactory source of nuclear heat for water desalting in those situations where nuclear is the logical economic choice.

In commenting on the proposed water conversion program, we will make only two recommendations. The first concerns plant construction and the second, research and development.

First, we recommend construction of a large water desalting plant now as the first prototype in a large plant development program.

Second, we recommend that the Office of Saline Water continue and expand its research program on methods of converting water.

Building the big plant now is, we believe, a crucially important step in the advancement of water conversion technology.

At this point, I would like to make clear that my remarks in favor of the early construction of a large plant relate entirely to the technical requirements of the desalting art. My company is able and willing to work for and with customers for such plants, whether they be from industry or the Government, or from both in some joint arrangement.

Consistent with our long time belief in the merits of our system of private enterprise, I would hope that private industry would see fit to build such a plant.

We recommend that this plant be built to a daily capacity of not less than 50 million gallons. Naturally, we recommend that it be built to fill an actual need in or near one of the large communities on an ocean coastline.

What are the reasons for building a full-scale plant at this time?

Well, the primary reason for building it is that this is precisely what the water program needs at this time. We are at the point where we have to learn what only a large-scale effort can teach us. The greatest advance we can make now will come through building the large plant.

Westinghouse is technically ready to build the plant. The Nation wants to see it built. There is very little to be gained by delay. We do not have to wait for some important discovery. There are no major problems of technology to be solved. In our opinion, the time to begin reaping the benefits of existing technology and to break the cost barrier is right now.

Where there is positive effort to improve at each step, every plant that is built in a new art like this should be markedly better than the one before it, both in performance and cost.

Point Loma was considerably better than the first generation plants at Kuwait. When the third generation plants are built, they will be considerably better than Point Loma. Such progress will continue even after we have mastered this new art and are building huge desalting plants routinely, because no technology is static and there is always more to be learned.

We learn by doing. For example, after Point Loma was in operation, the Office of Saline Water began to experiment with the technique of chemically pretreating the seawater before it became a river of hot brine. With an investment of only \$22,000 it increased Point Loma's capacity by 40 percent and broke through a temperature barrier that was blocking the path to more economical water conversion. This barrier had been set by the temperature at which severe scaling occurred. Further advances like this are what we need to achieve a quantum advance in the water desalting program.

When the 50-million-gallon-a-day plant is built, a true economic benchmark will be established by which to positively determine the economic trade off between plant size and water cost. Such a benchmark is a necessary yardstick by which we can measure our true progress in applying the knowledge accumulated to date. And when this plant has been built, and when its technical and economic feasibility has been demonstrated in actual operation, we believe that coastal communities in need of water will move to build more such plants which will be even better.

The first plants in a new art are always overdesigned to some extent, to allow for an extra engineering margin. They are heavily instrumented to permit special test procedures. Test data show, step by step, what the materials will do, which are better, and which are worse. On the next plant, the engineering margin is reduced and more effective use is made of the materials.

The obvious but highly important point here is that there is no substitute for hard, practical experience. Building a plant on paper, or as a test model, is one thing; building it to full scale in actual fact is a very different matter. If we had built Point Loma only on paper, there would be no flash evaporator plants operating today at 250 degrees. If we had built it only in a laboratory, I would not be able to make the statement that I am making here today.

There is a clear parallel between the development of atomic power as it stood a decade ago, and the development of water desalting as it stands today. This is true despite the infinitely more difficult problems encountered in building a nuclear reactor. I remember that on July 9, 1953, Mr. Gwilym A. Price, then president of Westinghouse, and Mr. Charles H. Weaver, then manager of our Atomic Power Division, testified on the atomic power program before the Joint Committee on Atomic Energy. The land-based prototype of the Nautilus reactor had gone critical some months earlier at the Idaho Test Station, thus demonstrating that the project was feasible. In his testimony, Mr. Weaver stressed, as I have today, the wide gap between making paper studies and actually building a full-scale installation. He described one of the most significant factors in the satisfactory progress of the Nautilus project. "We were given," he said, "a definite goal—a reactor to build instead of studies. And the goal was definite as to time also, with a working schedule established."

Another reason for building a large-scale desalting plant now is related to the probable consequences of carrying forward a water program without such a plant. First, our country will lose its position of technical leadership and, second, we will risk fragmenting our efforts.

We must remember that other countries are conducting strong water desalting programs. If we delay building a large-scale plant, other countries will be delighted. I mean to say that the competitive rivalry that is shaping up for this world market is as clear cut as it is in the supersonic air transport race or in atomic power. One thing is certain: large plants are going to be built and sold—if not in our country, then by some other country.

I know of no other field which, on a worldwide basis, is a subject of greater concern and is receiving more vigorous and enthusiastic attention than that of water resources. It is an area in which international cooperation can be developed and it is imperative that the United States maintain leadership.

Beyond this, I fear the consequences of spending too large a proportion of our effort—time, money, and talent—on small pilot plants and study projects. At the end of such a program, we still would not have the knowledge that comes only with building and operating a large desalting plant. We would not have demonstrated that large plants can produce low-cost water to satisfy a real community need. We certainly would not have carried out the “aggressive and imaginative program” President Johnson has called for.

In our opinion, such a program should include specific projects with firm and definitive goals, including both plant construction and research development. The toughest and at the same time the most meaningful goal will be a target cost for water under specified conditions.

Speaking for Westinghouse, I will state for the record that we are prepared to submit a firm bid on a large desalting plant at this time—50 million gallons per day, or 100 million, or 150 million, or larger, if desired. We will do this for a single-purpose desalting plant fueled by coal, oil, gas, or a nuclear reactor. Construction on this plant could begin immediately.

We will submit this bid on a turnkey firm price basis, with warranted capacity, warranted heat rate, warranted power consumption, warranted chemical consumption, warranted purity, and completion date. If the customer desires, we will also operate the water desalting plant for him. This ties down all the factors that go into determining the cost of producing water. In our opinion, the cost of water from a large plant bought on these terms can satisfy real and present needs in certain areas of the world today.

We realize the significance of such a statement as this. We are willing to make it because of our very considerable experience in the research, development, design, construction, and operation of water desalting plants, of power generation equipment, and of nuclear reactors—in short, all parts of the total plant.

Our other recommendation on the water conversion program is that the Office of Saline Water continue, intensify, and expand its research program on promising methods of converting water. We must find economic ways of purifying the brackish and mineral charged water

that is found in many inland areas of our country. The plants required to treat water that is not so impure as ocean salt water will presumably be of smaller size.

While any research and development program should, of course, be careful to look at all possibilities, it is important that major emphasis be put on those processes which appear most promising. The mere fact that a particular technique is novel and/or different does not necessarily warrant giving it attention that would detract from the principal efforts.

Research will also be required to find some practical method of reducing stream pollution by removing mine acids and other industrial wastes at the source. Westinghouse is actively engaged in such research.

As we see it, the water conversion program is now ready for a big step forward. The feasibility study recently ordered of a large, nuclear power and desalting plant for the Metropolitan Water District of Southern California is an evidence of an accelerating program, and it may provide the breakthrough in size the program needs. The bilateral agreement recently signed with Israel to conduct studies for a proposed nuclear power and desalting plant is another example of this progress.

In closing, I would like to refer once again to the great and overriding need for this program. The whole Nation was shocked this spring to read that New York City's reservoirs were only 40 percent full, and that water use there had to be limited. The availability of fresh water is obviously going to be a very great national problem in the years ahead.

It is reassuring that the problem is now receiving broad national attention, but much work lies ahead.

I thank the committee again for the privilege of testifying.

Senator ANDERSON. Mr. Simpson, you referred to the New York problem and the Los Angeles situation. You recognize, therefore, for the present these very large plants in very large cities and close to a boundless supply of water are desirable?

Mr. SIMPSON. Yes, sir.

Senator ANDERSON. That may change as the future comes along and the sizes come down.

Mr. SIMPSON. Yes, sir.

Senator ANDERSON. You mentioned on page 8 what happened at Point Loma. When Castro cut off our water supply at Guantanamo the first plant at Point Loma was shipped to Cuba. Were there any problems in the shipping of that plant?

Mr. SIMPSON. No, sir.

Senator ANDERSON. Did it start operating?

Mr. SIMPSON. There are always routine problems, but nothing serious.

Senator ANDERSON. Unusual problems?

Mr. SIMPSON. No unusual problems.

Senator ANDERSON. And the plant started operating?

Mr. SIMPSON. On schedule.

Senator ANDERSON. And is still operating?

Mr. SIMPSON. Still operating.

Senator ANDERSON. You state that we learn by doing. Did you replace the Point Loma plant?

Mr. SIMPSON. It has not been replaced, as yet. The Office of Saline Water is considering what plant to replace it with and whether it will be built at Point Loma or some other location.

Senator ANDERSON. Will the new plant have engineering advantages over the old plant?

Mr. SIMPSON. I am sure it will.

Senator ANDERSON. Then we learn by doing.

Mr. SIMPSON. Yes, sir.

Senator ANDERSON. I appreciate your statement.

Senator Allott?

Senator ALLOTT. Mr. Simpson, first of all I want to congratulate you on a very excellent statement. I was a little late and did not get a chance to hear the Secretary's statement although I have been looking through the long list of research contracts entered into by the Office of Saline Water with various institutions, corporations, and educational institutions.

In listening to your statement, what do you think a 50-million-gallon-per-day plant could produce water for?

Mr. SIMPSON. It would be 30 to 35 cents per thousand gallons. It is obvious that any time you give cost you have to give the circumstances under which you are talking—the cost of money and things like that. That would be at a plant where you could get the heat cost for 15 cents per million British thermal units; get the electricity for the pumping of the water within the plant at 3.5 mills; operate the plant at 95-percent load factor. The public water district financing, for example, is between 5.5 and 7 percent.

Senator ALLOTT. Well, in the latter part of your statement you have a rather firm statement, page 11, where you say that you will submit a bid on a turnkey, firm price basis, warranted heat rate, warranted power consumption, warranted chemical consumption, warranted purity, and completion date.

I assume that you believe that you have all of these factors under control at the present time?

Mr. SIMPSON. To build a state of the art plant that would do what we said with cost in the range of 30 to 35 cents and then we believe that a research program would be carried on in parallel with building a large plant which would enable the next generation plants to be better, not larger, possibly larger, but certainly better. By better, I mean the one overriding problem which is the cost in cents per thousand gallons. The fact that it is exotic and uses fancy materials, has nuclear power and what-have-you is immaterial. The thing that counts is the cost of the water.

Senator ALLOTT. When you made your statement, and I may misquote a little bit, you talked about taking or using the heat off of the extreme low end of the turbine. That is the exhaust?

Mr. SIMPSON. Yes, sir.

Senator ALLOTT. I assumed that was the exhaust. Some of us are not too familiar with engineering terms.

Mr. SIMPSON. And this could be the exhaust upon the last row of blades or could be extracted part way down the turbine between cylinders in the turbine or could have two turbines, one running back pressure using the exhaust and the other just generating electricity to balance out the load when you want power and when you want water

and this is a matter of engineering investigation as to what is the optimum for any given installation.

Senator ALLOTT. This is just a matter of utilizing heat that would otherwise be wasted?

Mr. SIMPSON. That is correct; heat that has been to such a low temperature and so far down the temperature end of the diagram that is not useful in the turbine, but still can be useful in the water-plant.

Senator ALLOTT. What portion of this research, in your opinion—and we have all been interested in this very greatly and especially those of us from the West who really have to deal with this problem in a thousand different ways almost every day—but what portion or area of the research do you believe that the Government should undertake and what should be undertaken by private industry when you say additional research should be done?

Mr. SIMPSON. There are two ways that you can progress. If there are enough plants to be built where a customer will buy plants, then there will be a margin of profit in these plants which private industry can use to do research. I believe that private industry could do the research in almost all instances, either with private financing or with Government financing under contracts with the Government.

Senator ALLOTT. Well, Mr. Simpson, in your statement you are obviously—and I do not say this critically because I think you are completely within your rights—you are obviously making a very strong pitch for your own efforts in this field. That is fine.

Mr. SIMPSON. Yes, sir.

Senator ALLOTT. I congratulate you on that. But you are obviously interested in the sale of plants under the terms or conditions you describe on page 11, and I am not critical of this. I applaud it. I think it is fine. So, therefore, if Westinghouse were to be selected for the construction of a 50-million-gallons-per-day plant, say in the Los Angeles area as an example, you would be interested in building this. You recognize the competitive situation because you refer repeatedly to the fact that these plants are going to be built and sold on a worldwide basis. Therefore, you are going to do a considerable amount of research to be assured that the plant that you would build betters the plant—if you can possibly do it—that anybody else would build. Is this correct?

Mr. SIMPSON. Yes, sir.

Senator ALLOTT. It is impossible for a person of nonscientific education, by looking at this list of research contracts, to properly determine whether some of these research contracts contribute directly or could have been expected to contribute directly to the state of the art and to the advancement of this whole research field. This is the reason I ask you these questions as to what could be done by way of research. How much should the private manufacturer bear? How much should the Government bear, and particularly I am thinking in what terms or in what areas should the Government project its research?

Mr. SIMPSON. Well, in the Point Loma plant, as an example, the Office of Saline Water took bids and we were the successful bidder to furnish a product under full guaranty. It was not a cost-type contract or a research contract. It was a contract with the Government

to produce a plant that would have a guaranteed production of water under certain conditions.

The research that had to go into the building of that plant we had to do as a private venture. It was done and the plant was successful. Now, that is one mechanism of doing research. I do believe that the research should not be fragmented. If you have 50 different companies all spending \$10,000 or \$20,000 or \$50,000 or \$100,000 on research the Government or the people will not get near the results out of it as if you have a smaller number which we used to call in the atomic power business a critical mass of technologists and technology working on the problem. You hardly get started on some of the small contracts and then the question is, do you continue or do you stop, and it is fragmenting and it needs a vehicle to build a large plant to focus the research on the problems that are needed, and not end up with a hodgepodge of knowledge that does not make a whole, to build a plant.

Senator ALLOTT. Well, you have already pointed out that it does not make any difference what source of power you use.

Mr. SIMPSON. Just the cheapest power.

Senator ALLOTT. Just the cheapest power available at a given source. We now have the plant at Freeport, Tex., and flash distillation at San Diego. Is that your plant?

Mr. SIMPSON. The one at San Diego is ours; yes, sir.

Senator ALLOTT. The one using electrodialysis in South Dakota, that is not your plant?

Mr. SIMPSON. No. Our only plant was the Point Loma plant. Now that is for the Government. The other plants we have built are in the Bahamas and all around.

Senator ALLOTT. I am talking about the five the Government is interested in.

Mr. SIMPSON. No; we only have the one.

Senator ALLOTT. The Government has one in New Mexico, and one at Wrightsville Beach, N.C., which is a freezing plant. I do not want to ask you this question and embarrass you, but in looking over this long list of so-called research contracts, I wonder how much—because of your confidence in your own system which I think is fine—these research contracts have contributed to your own knowledge and efficiency in this field?

Mr. SIMPSON. Nothing. I guess that does not say they could not. It simply says we have received no information from these recent contracts. Most of the contracts have just been let, and therefore, there are no results from them.

Senator ALLOTT. You are talking about the contracts?

Mr. SIMPSON. The list of contracts that I thought you were referring to.

Senator ALLOTT. No.

Mr. SIMPSON. You mean the five plants?

Senator ALLOTT. You are referring now to the five plants. I am talking about the dozens of research contracts that Mr. Udall attached to his statement and wondered how much of the material is available to you.

Mr. SIMPSON. I have not seen the list which I think you are referring to.

Senator ALLOTT. And here you are speaking of a purely private enterprise endeavor in which you have great confidence and I just wondered how much the knowledge or efforts contained in all these research contracts that have been let by the Federal Government have contributed to the knowledge of your company in making it a more successful operation.

Mr. SIMPSON. Well, the five plants that were built were such five different processes that clearly the technology that was gained in those is of major advantage if you pursue that particular process. We happen to be pursuing but one of the five processes. We are working on flash evaporation; therefore what they learned from freezing is not of much benefit to us. It may be of benefit to somebody else who may want to work on freezing.

Likewise, many small research contracts have been let. I am sure we have gotten something out of that, but most of them have not come to fruition yet.

Senator ALLOTT. All right, here is a contract No. 253 let to Alpha R. & D., Inc., in 1962-63, prevention of corrosion. Then the next one is to Battelle Memorial Institute, "Corrosion Mechanisms"; next one to Battelle again, "Corrosion of Selected Materials in Hot Sea Water." Let us be specific. Have any one of these three contracts on corrosion that you know of contributed directly or indirectly to the knowledge of Westinghouse on the effects of corrosion?

Mr. SIMPSON. No, sir; they have not. I do not want to be unfair here because I do not know whether those contracts have ever been implemented yet.

Senator ALLOTT. Well, these were let in 1962 and 1963.

Mr. SIMPSON. That is a long time ago.

Senator ALLOTT. 1964, for instance.

Mr. SIMPSON. They did not help us because we happened to have done our own research on the corrosion of materials we intended to use in construction and, therefore, it was not germane to our effort.

This does not say that it was not valuable information. It just simply was not germane to what we were doing.

Senator ALLOTT. I see. As I look through this list of contracts, I see that some of them are pertinent only, of course, to particular processes of these five plants, but the real thing I am getting at is—I know the chairman knows that I am very much concerned, deeply concerned about it—the duplication of research in this country, financed by the Government, and research that is being done in areas which is already the knowledge of either the public domain, or the universities, or private companies in the United States. If we could cut out of these efforts, for example, several millions of dollars in duplicative or wasted research, we could put that much more into a practical effort to attain a really competitive and economic desalination plant or program.

I am sure you would agree with that, would you not?

Mr. SIMPSON. Yes, sir.

Senator ALLOTT. That is all I have, Mr. Chairman.

(Subsequent to the hearing Mr. Simpson supplied the following information:)

WESTINGHOUSE ELECTRIC CORP.,
Washington, D.C., May 20, 1965.

HON. CLINTON P. ANDERSON,
U.S. Senate, Washington, D.C.

DEAR SENATOR ANDERSON: In the course of my appearance before your subcommittee on May 18, 1965, Senator Allott asked several questions concerning Westinghouse opinion of research and development contracts let by the Office of Saline Water. Unfortunately, I am afraid, there may have been a misunderstanding of our position in this matter, and I would like to clarify that position.

Westinghouse has benefited tremendously from its participation in the OSW program. The lessons we learned by building and putting into operation the Point Loma plant have been invaluable to our commercial operations in the water conversion field. Many of the OSW contracts relate to areas which we are not actively pursuing and are, therefore, of no practical value to us. Nevertheless, we follow such work closely in order that we may profit from any results which could affect our business. Some of the OSW contracts are aimed at technology in which we consider ourselves already knowledgeable, having pursued the same objectives through company-funded efforts.

This may not have been clear at the hearings, because while Senator Allott was referring to a total listing of OSW research and development contracts, I thought he was referring to the list of contracts awarded in the third fiscal quarter, a list which appeared in a Department of the Interior press release on May 17, 1965.

I would hope to have an opportunity to reflect our true position more clearly through minor changes in the transcript of the hearings. In any event, I appreciate greatly Mr. Di Luzio's thoughtful attempt to clarify what he, too, felt may have been a possible erroneous impression created during the course of my testimony.

Once again, I wish to express our thanks for the opportunity to participate in hearings on this extremely important program.

Very truly yours,

JOHN W. SIMPSON,
Vice President, Electric Utility Group.

Senator ANDERSON. I only want to say that some of this research may be different now and that is one of the reasons I have been very happy with the results of our program in building plants. I introduced Senate Resolution 135 having to do with the building of plants because, as you pointed out, you learn by doing.

Mr. SIMPSON. Yes, sir.

Senator ANDERSON. And you point out that on some of the research on the projects you, yourself, found out what you could do with higher temperatures.

Mr. SIMPSON. Yes, sir.

Senator ANDERSON. And that is why I tried to shift the program to things where you learn by doing instead of contracts on research without leading to any one particular accomplishment.

Mr. SIMPSON. I feel the five plants were highly useful, even the ones that did not work or the ones that were not successful, because it proved what was good and what was better and what was best. That is highly important information to have.

Senator ANDERSON. Well, Mr. Simpson, some years ago there was a great tendency to accept too much theory. The Zarchin process was a very workable one on paper and it was thought would revolutionize the whole business of saline water. Somebody tried it out and found it would not work.

Mr. SIMPSON. Negative information in the research field is as important as positive information.

Senator ANDERSON. If we had not turned our attention to Point Loma and built a plant that was working and working well we would not have been able to solve one problem with Mr. Castro. We moved that plant down there.

Senator Moss?

Senator Moss. Is there any preference for the type of fuel to be used? You said it could be gas or coal or atomic energy. Can you draw any line for me as to which is more economical and useful?

Mr. SIMPSON. Well, if you are building a plant in the vicinity of Corpus Christi, where they do have a water shortage and they have gas rather cheaply, I would suspect gas would be the cheapest fuel. If you are building a plant in California, I would suspect that atomic energy might well be the cheapest there.

The average cost goes almost like electric generating stations, the heat being about the same, and it depends upon the cost of coal, oil, or gas. In the Bahamas, I would suspect if you needed a big enough plant, nuclear would be the cheapest; if not, another fuel.

Senator Moss. In other words, you are saying there is no particular advantage in any one of the types of fuel. It is simply the economics of getting it there to use it.

Mr. SIMPSON. Yes, sir; fuel has a heat content and you take the delivered cost of the heat and whichever supplier will supply you the heat the cheapest, that is the man you buy it from.

Senator Moss. Thank you.

Senator ANDERSON. Senator Burdick.

Senator BURDICK. No questions.

Senator ANDERSON. Thank you very much, Mr. Simpson.

I see that Dr. Hornig is now here. We will be very happy to hear from him.

STATEMENT OF HON. DONALD F. HORNIG, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY

Mr. HORNIG. Mr. Chairman and members of the committee, it is a pleasure to appear before the committee this morning and to share with you some of my views concerning our program for the desalting of water. I shall not dwell on the need for new sources of fresh water. In his message transmitting proposed legislation to extend the research program in desalting, the President clearly stated the need for developing new sources of fresh water at costs which are competitive with those to be expected from the sources we have been tapping.

There are, of course, a variety of needs ranging from the large scale production of agricultural water at costs under 5 cents per thousand gallons, or \$15 per acre-foot—a goal to which we cannot yet see a solution—to the large-scale production of municipal and industrial water supplies at 25 or 35 cents per thousand gallons, the goal to which the present program is predominantly addressed. A separate problem and a great need is for much smaller scale water supplies for the many communities in the midcontinent depending upon brackish ground water at prices which, in some circumstances, may range as high as \$1.50 or \$2 per thousand gallons.

Impetus for the proposed new program has arisen to a considerable extent from a report prepared by an interagency task group for the

Office of Science and Technology in March 1964. This report assessed the suggestion of AEC scientists that very large-scale, nuclear-powered, sea-water distillation was economic. After going over the problem in considerable detail, the task force concluded that, depending on the basis of financing, dual-purpose plants using current distillation technology, producing electric power as well as water, when scaled up to capacities approaching 500 million gallons of water per day and 200 megawatts of electric power might be expected to yield water at costs between 25 and 30 cents per thousand gallons, that is \$75 to \$90 per acre-foot.

A process such as envisioned in the report might well be competitive now for the production of municipal and industrial water. However, it would involve construction of plants more than 100 times as big as any yet built. This involves formidable engineering problems and the central thrust of the new program is to pursue the engineering development leading to such plants, and if possible, to reduce the cost of water below the levels envisioned in the report. Of course, the number of localities in this country at which such volumes of municipal and industrial water and such electric power levels can be simultaneously consumed is limited. To broaden the benefits of the program it is most important to find ways of reducing costs well below those that can be obtained by a simple scale up of the current state of the art so as to provide economically competitive water in smaller plant sizes, perhaps 50,000 to 100,000 gallons per day.

If we are to reach this goal, we will have to undertake a program of intensive research on new materials and simplified processes which will reduce the capital investment in such plants and the requirements for heat. The proposed bill authorizes the funding of such a program. To cut costs, studies will have to be made on heat transfer, the problems of scale deposits, new and cheaper materials for use in desalting plants, and so on. It is probable that no single breakthrough will mark the first major successes, but rather a combination of many scientific advances and substantial amounts of engineering ingenuity.

Laboratory work alone will not suffice. To reach a practical goal at an early time will require the construction of pilot units to test new methods and concepts and the construction of modules which are segments of large-scale plants but not in themselves complete or economic production facilities.

The next stage, and one which ought to be undertaken as early as possible, is the construction of a prototype plant. A word may be in order as to what I mean by a prototype plant. A prototype plant is a full-scale production facility which is a first model of later operational facilities. It should utilize the most advanced technology available at the time it is constructed. Indeed, it should stretch our technology to the limit, for only through this stretching can a prototype plant serve as a stepping stone to truly efficient and reliable operational plants. A prototype plant should be distinguished from a demonstration plant. If we move too early to plants which demonstrate what can be done operationally, we will not be pushing forward satisfactorily toward meeting the ultimate goals. For this reason, a prototype plant need not itself be economical; it should teach us how to build an economical operational plant.

The proper definition of the first prototype plant should properly depend on both the results of the R. & D. program and on the estimates and conceptual studies produced by our advanced engineering and industrial firms.

In my opening remarks, I stated that water costs from natural sources now range from less than 5 cents to over \$2 per thousand gallons. Thus, when we use the words "competitive cost," they have no specific meaning. A plant producing water at \$1 per 1,000 gallons might be competitive with conventional supplies in one locality, but this cost could be outrageously high for another area more favorably located with respect to water resources or with a larger demand.

Present technology is, therefore, capable of meeting immediate needs in some specific problem areas where current water costs are high or where adequate fresh water is unavailable, regardless of cost. Industry has been supplying desalting plants in such locations for some years and is continuing to do so. These plants have generally had capacities of less than 1 million gallons per day, but have ranged up to as high as 2.5 million gallons per day.

It is not yet clear whether industry can, in the immediate future, adapt current technology to the design of plants which will produce a competitive water supply in areas where the cost of conventional water supplies is relatively low. The large-scale industrial interest in the desalting effort and the conceptual studies which are being undertaken by many firms have increased the effort devoted to the problem and brought a force of ingenious men into the field. It is possible, as has occurred often in the past on other problems, that when imaginative men get to work on a problem we will see that workable and economical plants can be designed right now, even before much development has gone forward. However, the promises and designs will have to be verified. We have had much experience in military research and development with promises which outstrip the ability to perform, and paper gains which have gone under the name of "brochuremanship." It is for this reason that we must press both an R. & D. program and the industrial design effort. I would like to interpolate at this point in considering various statements of cost, where it must be remembered that all cost numbers must be tied to such things as the basis of financing, the price charged for the input heat, and so on. Most of the many numbers quoted are incomparable to each other unless the basis of costing is established in the first place.

By either route it is clear that we will need to build a prototype plant on a suitable scale at an early point in time if we are to get our feet on the ground and see where we stand. The fact that industry may already be able to provide plants which are acceptable in some locations or for some users does not signal the end of the problem. We must be looking toward second- and third-generation plants.

The main thrust of the new program, as I have mentioned, is toward very large scale distillation plants. A quite separate problem is that of the small plant, a few million gallons per day, or less. Such small plants are needed to process brackish water in the central and western interior of the country. It is unlikely that the distillation processes can be sufficiently economic for this purpose, but the various membrane processes hold enormous potential for the future. Much research on the properties and fabrication of membranes and their practical application will be necessary before truly low-cost water is possible.

One of the complicating features of research on desalting brackish and waste waters is the wide diversity in the chemical composition of these waters. A process which is highly successful in one application may encounter serious difficulties in others. That is not an insurmountable obstacle, but simply another variation that must be coped with.

The membrane processes may also prove useful in processing waste water from industries and municipalities for reuse. Some 60 billion gallons of such waste waters are produced daily. They contain from a few hundred to perhaps 2,000 parts per million of salts. These waters, because they are already at centers of use, may be reclaimed at costs competitive with the cost of providing "new" water in many instances.

In the long run, it seems likely that membrane processes can be developed to the point where they will become the most efficient means of desalting sea water. This possibility is certainly not practicable now, but the membrane research which is currently aimed at small-scale plants is likely to provide the technological base for future generations of large-scale plants.

The great dream of the future is to provide desalted water for agriculture. Such a goal is not in sight. We cannot even promise its attainment in the near future for extremely high value crops. Nevertheless, the goal is not theoretically impossible. It may even be possible to achieve selected removal of salts so that desirable salts can be retained and undesirable ones rejected. We will not reach these goals—indeed, we will not even know whether we can reach them—if we do not move forward with the next phase of desalting research through the program which has been proposed by this administration.

Thank you, very much, Mr. Chairman.

Senator ANDERSON. Thank you, Dr. Hornig.

You referred to the membrane processes and said they offer some real possibilities that we can work out. Is the plant at Webster, S. Dak., a membrane process?

Mr. HORNIG. The plant at Webster processes I believe by electro-dialysis. That is my guess.

Senator ANDERSON. There were several proposals made to Interior for the use of the membrane process and it may be tested and may be found wanting, but do you think the work would still be worthwhile because it offers possibilities for the future?

Mr. HORNIG. The whole question of membrane technology is one in which there is still very much basic work to be done. There is no simple thing that one can call a membrane.

There are very many kinds of membranes; to make membrane plants practicable, when these membranes which have a high rejection rate on salts which do not clog up, would be impurities in water which will not break under the pressure of the water against them, so that I think the development of the membrane process is dependent very largely on our learning to make the right kind of membranes and then put them into suitable engineering use.

Senator ANDERSON. One of the firms manufacturing brackish water operation equipment has offered to put a few of these operations on ranches. Have you found a rancher that would want to try it out and test it out? Does it not indicate they are very sensitive of the

fact there might be a fairly good market for these processes if they can get them down to the reasonable cost?

Mr. HORNIG. I think there is likely to be a good market. The membrane process is in the immediate future and likely to be the most promising one on a small scale, for smaller units, ranches, and water systems for very small towns.

Senator ANDERSON. Are you talking about the dream of the future to provide these small waterplants? We do have to make use of these costs once in a while and obviously nobody is talking about a cost of getting down to 5 or 10 cents per thousand gallons. Unless he does, it is not very practical from the standpoint of agriculture. I am glad you have said this is not in sight. It might come but it is sometime in the future. In the meantime, these studies are bringing down the cost very materially. Actually, now these desalting processes are used in steamships and other vessels.

Mr. HORNIG. Yes, water is desalted, input water for big industrial plants, and the installation is used on steamships.

Senator ANDERSON. Those are costly, are they not?

Mr. HORNIG. They are all costly.

Senator ANDERSON. But that does not mean we should stop research on what might essentially be the solution to our problem at home.

Mr. HORNIG. As I indicated, this whole word "competitive" and "cost" must be related to what you want to use the water for and what your alternatives are.

Senator ANDERSON. Of the water research budget, do you know how much is being put in desalting research?

Mr. HORNIG. I believe it is \$26 million that was budgeted for research and development.

Senator ANDERSON. Have you been having in your Office much assistance from nongovernmental people in connection with this Government research project on this subject?

Mr. HORNIG. Yes, I have consulted with many industrial institutions.

Senator ANDERSON. Have they any comments on the scale proposed for the desalting research?

Mr. HORNIG. I think it is the general view that the time is ripe to go forward.

Senator ANDERSON. Thank you, very much.

Senator Allott?

Senator ALLOTT. Doctor, just a question or two. What is the situation with the plant at Wrightsville Beach, N.C.? That is the so-called freezing plant. What has been the results of that research there?

Mr. HORNIG. I am afraid I cannot answer that question in detail. Wrightsville Beach, of course, is a pilot plant rather than an operating plant.

Senator ALLOTT. The point of my question is that as I understand it the Wrightsville plant, as a pilot plant, has not been too successful, and that we do not continue with these programs which do not show any promise and continue to pour untold millions of dollars into them. I would rather see us pick up the areas which do show promise. We do not have a pilot membrane plant now; is that correct?

Mr. HORNIG. We have electrodialysis plants which are a membrane process; yes.

Senator ALLOTT. The reason I asked is because Senator Anderson asked whether the plant at Webster, S. Dak., was a membrane plant and you replied "electrodialysis." So there is one plant using a membrane process in South Dakota.

Mr. HORNIG. Yes, sir. I want to make clear that new membranes and new kinds of membranes are made every day in many parts of the country so that one plant does not close the subject.

Senator ALLOTT. Well, I am not criticizing you in this respect because you apparently are quite sold on the future possibilities of the membrane process and you pointed out that this may vary from region to region in each part of the country depending upon the chemical composition of the water.

There is a small city in Colorado not far from where I live which has a very, very critical water situation. It is so located that wells, or water from the Arkansas River, or water from its tributaries all bear a higher proportion of salts, I believe, than the water we are delivering to Mexico and about which they are screaming.

Senator ANDERSON. Yet, they are thriving.

Senator ALLOTT. Yes; and they are thriving on it, too.

Mr. HORNIG. They have a hard time washing their clothes, I bet.

Senator ALLOTT. Well, you only have to jump into the bathtub three times, and you finally get in the third time. But I would like to see some of this effort directed to smaller communities of this type. There may be others in Colorado. I am sure there are communities of this type throughout the entire West. This particular community made a very valiant effort to try to get some kind of program and I would like to see some effort made to help them.

Now, there is one other thing you mentioned in your statement which interested me very greatly. This is the amount of water which could be rehabilitated at the source of discharge from municipalities, from industrial plants, and from mines, which also put pollution into streams at times, depending upon the operation. In order to accomplish anything real in this area, are we not going to have to have more stringent laws with respect to stream pollution before we can do anything?

I use, specifically, the example of the "cesspool" that runs through Washington. They were talking about it when I arrived here some 11 years ago, and they are still talking about it. I can see no appreciable difference during the months of July and August when you drive by that area.

Do we not really need a completely new look at substantive legislation which will give the Federal Government the means to control the pollution in these interstate streams and the navigable waters?

Mr. HORNIG. I think the answer is "Yes." The President is concerned about the pollution problem. An effort of the President's Science Committee is a study of the pollution problem and what steps might be taken and so I think that it is quite clear that we are going to have to take steps to reduce the pollution at its source.

Senator ALLOTT. I think your statement is a very significant one, in that by placing a certain amount of effort at the river source where cities dump their pollution and where industrial plants tend to pollute the waters, that here you might recapture the water at a much lesser cost than you could do it by utilizing some of the processes that

we have been talking about. Utilizing this technique you could do it with much less cost than, in some instances, by trying to recapture new water, or what you call new water.

Mr. HORNIG. Yes; that is correct.

Senator ALLOTT. I think that is all I have. Thank you, very much.

Senator ANDERSON. Senator Burdick?

Senator BURDICK. Thank you, Mr. Chairman.

Mr. Simpson, who was the previous witness, testified as follows:

We are pushing ahead with construction of a multistage plant because we have found that no other process approaches the technical ability and overall economy of this effort.

Do you agree we have arrived at that conclusion in regard to the large plants?

Mr. HORNIG. Yes; for large-scale desalting of sea water I think that I would concur in that.

Senator BURDICK. Then the accent of your testimony today is upon the smaller plants.

Mr. HORNIG. No, I think what I said was that the principal thrust of our program is for the large scale, but a separate, quite separate problem, which is also very important, is the desalting of brackish water. I would not concur that distillation is the most economical means of coping with brackish water on a much smaller scale.

Senator BURDICK. And you recommend the building of a prototype plant for the smaller areas?

Mr. HORNIG. I think that any R. & D. problem leading to operational plants must first accumulate the knowledge and then set up small-scale pilot plants to sort out processes and before you build the plants, certainly a prototype plant must be built as Mr. Simpson indicated, to find out in a hard way what the operational problems are.

Senator BURDICK. What processes would you try first in the smaller plants?

Mr. HORNIG. I think in the smaller plants, it is likely that one or the other of the membrane processes which include electrodialysis, reverse osmosis and this has to be sorted out by technical evaluation and particular processes in detail.

Senator BURDICK. And this would be a plant that was scientifically different than the one in South Dakota, of course.

Mr. HORNIG. A newer one would undoubtedly use newer membranes and different details of the design, yes; just as at the Point Loma plant. In fact, Point Loma profited and improved from its efficiency and to some extent its design in its own lifetime so that I would hope at this stage that each new plant is a significant improvement on what we have built before.

Senator BURDICK. What you are saying, in effect, is when we pursue this large plant, we should not forget the local areas either.

Mr. HORNIG. That is correct. I say we should pursue both problems, the local ones and the large-scale ones.

Senator BURDICK. Thank you.

Senator ANDERSON. Well, I am glad Senator Burdick, you made that statement because I was very much interested in the offer of this company last fall. I realize the cost of running a small plant by a rancher, which might be \$5 per thousand gallons, would be well worth it to him whereas it would not be worth it to somebody who lives on the

Pacific coast. But 30 to 35 cents for domestic water is a fairly reasonable price; is it not?

Mr. HORNIG. Yes.

Senator ANDERSON. Yet that does not provide for agricultural water. We will have to get way down below that for agricultural water. So we want to see the plant improved and hold back that part of the program until the price is right.

Mr. HORNIG. That is right.

Senator ANDERSON. Thank you very much, Dr. Hornig.

Our next witness is Mr. John W. Pike, president, Struthers Scientific & International Corp.

STATEMENT OF JOHN W. PIKE, PRESIDENT, STRUTHERS SCIENTIFIC & INTERNATIONAL CORP.

Mr. PIKE. Mr. Chairman and members of the committee, my name is John W. Pike. I am president of Struthers Scientific & International Corp., of New York City, a subsidiary of Struthers Wells Corp. Our company has participated in the development of freezing—one of the new techniques in the art of desalination which the Office of Saline Water has sponsored as part of its research and development program.

As the world's growing water needs become more acute, we evaluated the various approaches possible to produce potable water from sea, polluted, and brackish waters.

Our parent company for more than a century has been one of the Nation's leading engineers, designers, and manufacturers of specialized process equipment for the chemical, petrochemical, petroleum, and power industries. Just recently, the Bureau of Mines, U.S. Department of Interior, in a special study, reported that thermal secondary oil recovery has enabled this country to consider its usable oil reserves at twice the former estimate. By 1980, the Department predicts perhaps 50 percent of all U.S. crude oil production will come from secondary oil projects. Struthers Wells engineers pioneered the development of our thermoflood equipment, which was introduced for steam flood secondary oil recovery and represents a great contribution to the Nation's conservation program.

Our company has been involved in distillation methods for many years. Struthers has engineered and fabricated distillation plants for the chemical, petrochemical, and petroleum refining industries. In fact, we are presently offering distillation plants for water purification based on our background and through an agreement with W. L. Badger Associates, Inc., utilizing the technology developed in the Freeport, Tex., Falling Film Evaporator plant designed by Badger Associates for the Office of Saline Water. Considerable know-how has been obtained from the Freeport plant, and today Falling Film Evaporation is an advanced and mature distillation method which we feel fulfills a specific purpose in our overall capability to provide a broad solution to water needs.

Senator ANDERSON. Mr. Pike, I am glad you mentioned Mr. Badger, the W. L. Badger Associates, because at one of our earlier hearings on the use of desalination processes one of the best witnesses we had

came from that organization, so I know they are not novices in this field.

Mr. PIKE. He was a great gentleman. I knew him personally.

Senator ANDERSON. He certainly was.

Mr. PIKE. Meanwhile, we reviewed our corporate capabilities and decided that we had sufficient technology to develop a freezing process as a more efficient means to remove fresh, pure water from brine because of freezing's chief advantages: Low-energy requirements, lower cost plant due to decreased corrosion and no scale formation. We based our work in freezing on more than three decades of technology developed in conjunction with our controlled crystallization engineering for the process industries. More than 30 years ago, we acquired and further perfected the Krystal process for growing large, uniform size and shaped crystals. From this technology, widely used in the chemical, fertilizer, and pharmaceutical fields, we have developed methods to grow large, uniform ice crystals which can be easily separated from brine.

We began our efforts at our Warren, Pa., laboratories conducting bench-scale, pilot-plant research and under an initial grant from the Office of Saline Water about 6 years ago further perfected this method. These developments were the outgrowth of work directed by Hans Svanoë, an internationally known expert on crystallization. He has had a lifelong interest in producing fresh water from the sea, and has built a capable staff around him. Mr. Svanoë is the holder of many significant patents in the field of crystallization and crystallization processes. Additionally, our staff includes such respected people as Stephen A. Laurich and others we have carefully trained in these techniques throughout our history in the field.

Senator ANDERSON. Let me interrupt again. Senator Allott was interested in knowing what some of these small research contracts and grants had developed and we have actual information. I read your testimony here that you did this work under grants from the Office of Saline Water.

Mr. PIKE. Yes, sir. We began on our own in a small way and, as I say, 6 years ago we got an initial grant which was a partial subsidy of the U.S. Government.

I may add that we believe very strongly in research programs and the research approach to perfection of a technique. I think our country as it exists today is an outcome of this attention to basic research and the development of techniques through research.

Senator ANDERSON. Well, I appreciate your statement because it is somewhat in answer to the question that Senator Allott raised. I think a great many of these contracts are extremely productive and very useful to the Government and I am glad your company had this sort of grant while it perfected its own work in a very important field.

Mr. PIKE. Yes, sir.

About 1954, similar research work in freezing was started in Japan under the direction of Dr. Shuji Umamo. Although the aim of this program was to perfect an efficient method for producing brine for the salt-short Japanese chemical industry, this technology was similar to the work we were doing in the United States. Struthers Scientific acquired the patents and know-how, along with the services of Dr. Umamo, during 1962, incorporating this additional capability into our

own process. During 1964, we also acquired the rights to patents, know-how, personnel and research facilities on the Pacific Coast at Oxnard, Calif., of the Rocketdyne Division of North American Aviation, Inc. We also obtained by this acquisition the services of Drs. Manuel H. Gorin and Ludwig Rosenstein who have major inventions in the direct contact heat exchange field and other improvements in the freezing process as well as rights to patents developed by Esso Research Corp.

It is this combination of technology, people, and facilities which we have put together to continue development work and experimentation to further perfect a new process—freezing—on a broad scientific and engineering basis. Today we have a skilled group which is a nucleus to further broaden our capability. Although we have made much progress in a short time—compared to years available to older heat processes—there yet remains much work to be done. Any program of this type is based on trial and error—what we learn today allows us to take another step forward tomorrow. Progress—scientific progress—can be achieved only through continued developmental work on a meaningful scale by dedicated people bent on success. Sometimes progress has been painfully slow as we have isolated and solved the many mechanical and technical problems inherent in any developmental program of this type.

Much has been accomplished since the Office of Saline Water first began work in this field little more than a decade ago. The cost of producing fresh water by older distillation methods was as high as \$4 per thousand gallons. Today, after 10 years of continued research work, the figure has been reduced to about \$1.

Meanwhile, freezing and other new types of processes—which were little more than ideas 10 years ago—have made strides forward. According to studies and projections of the Office of Saline Water, the United Nations and various learned institutions, the freezing process has considerable promise as a method to produce fresh water from sea and brackish water. Certainly it has the advantage of requiring considerably less energy, in addition to those advantages previously outlined.

We estimate that only \$18 million has been invested toward perfecting the freezing process—about \$6 million has been sponsored by the U.S. Government and the balance by private industry and foreign governments. In terms of major development programs, this amount of money is relatively insignificant. Industry and governments have spent several hundred million dollars on development of and plants for distillation. Combined with the short period of time, we must conclude therefore that considerable progress has been made in developing freezing as a process for economically removing fresh water from sub-standard sources. Based on this minimal expenditure of time and moneys, it is reasonable to project significant incremental progress with additional investment.

In the freezing process, much has been learned so that work can go forward. There is still much to be learned. Many of the mechanical problems which are inherent in any new process have been solved. It has been demonstrated that our direct contact controlled crystallization freezing process can produce fresh water, and with further

experimentation we can heighten its economics and further perfect its operational characteristics.

Recently, at the 15,000-gallon-per-day pilot plant at Wrightsville Beach, N.C., sponsored by the Office of Saline Water, using our freezing process, pure ice particles as large as one-fourth inch in diameter were produced. This diameter was at least four times larger than contemplated—and demonstrates how major improvements are achieved through development.

Although experimental work on a form of separation—using a centrifuge—has only recently begun, the process has been demonstrated using a wash separation column which has separated one-half ton of ice per hour per square foot from an ice brine slurry—more than ever previously accomplished in a wash column. This piece of apparatus was designed by the Office of Saline Water from experimental data resulting from one of their research contracts. The results demonstrate how large ice crystals can improve separation efficiency.

These are some of the things we have learned in our experimental, trial-and-error efforts in the pilot plant. We have developed and transferred this information to the larger 200,000-gallon-per-day pilot plant also located at Wrightsville Beach. In the future these concepts can provide the necessary and reliable engineering and economic data from which larger freezing plants may be designed, installed, and operated.

Although we have developed an operable freezing process based on one series of criteria, basic research in the new art of freezing remains necessary as in other processes. There are many ideas which, while sound in principle, are only experimental in nature. Engineering and pilot plant experience and analysis are necessary to provide data to decide whether or not to incorporate them into process design of larger plants. These programs are vital in the continued experimentation needed to speed development of freezing as an economic, fresh water producing technique.

Freezing also has a unique role to play in brackish and polluted water conversion in the salinity ranges of 9,000 to 20,000 p.p.m., as well as in plant sizes from 1 to 10 million gallons per day. For every plant contemplated in the future with a capacity of 100 million gallons per day, we estimate that there will be at least 100 plants of under 10 million gallons per day. Electrodialysis, although suitable for lower salinities, is too expensive in the salinity ranges of 9,000 to 20,000 p.p.m. And, because of the typical higher concentration of scale-forming compounds in brackish waters, heat or evaporation or distillation processes require expensive treatment to remove these scaling compounds. Freezing, because of low-operating temperatures, largely eliminates scale.

Further knowledge can be gained by operating pilot plants of both large and small sizes so that what is learned in small plants can be quickly transferred to a larger scale, or what cannot be done on a trial-and-error basis in large plants can be quickly and economically tested in small plants and transferred if proved correct.

In summary, we believe the following should be accomplished in the coming year to accelerate development of the promising freezing process and that adequate funds be allocated for this purpose:

1. Continued operation of the pilot plants of various sizes to perfect

and optimize known process technology and equipment design on an accelerated basis.

2. Programs to develop new equipment designs and process concepts should be accelerated.

3. Continue basic research and development studies to learn more about the physical mechanisms underlying freezing technology.

4. Undertake engineering and economic studies on large-scale freeze desalination plants.

Since this program does not involve design and installation of large plants requiring major equipment procurement during this fiscal year, the expenditures required are relatively small compared with the expected achievements. However, we believe that substantial funds should be provided during the coming fiscal years to achieve the development of a low-cost freezing desalination process.

We, who have invested so much of our own time, effort, money, and talent toward building a trained and skilled team and achieving a perfected freezing process, are confident that the President's vision of breakthroughs, and the Department of Interior's dedication and implementation of its program to make available economic pure water throughout the world can be achieved.

Thank you for the opportunity to present these views.

Senator ANDERSON. I appreciate your coming and the work your company is doing. This bears out what we have been talking about. Somebody complains that flash distillation is the best way to do this and somebody else is attracted to the membrane system and maybe the freezing process will work. That is why I am hopeful the people who believe these things will test them and all come up with some process, maybe two or three that are useful and valuable to us.

I appreciate your appearing today.

Mr. PIKE. Thank you, sir.

Senator ANDERSON. Our next witness is Mr. Philip D. Bush, vice president of Kaiser Engineers.

Mr. Bush, I do not want to disturb you before we get started, but we have had four witnesses in a matter of 2 hours and we are going to go on for another hour and a half or possibly 2 hours. This is a rather long presentation to be given and the Chair is going to put the entire paper into the record and I wish you would highlight as much as you can of your statement.

STATEMENT OF PHILIP D. BUSH, VICE PRESIDENT, KAISER ENGINEERS, DIVISION OF THE KAISER INDUSTRIES CORP.

Mr. BUSH. Mr. Chairman, I had no intention of reading this report to you. I had summarized this and will present it in about 12 minutes. If you prefer to do it after lunch I will be agreeable.

Senator ANDERSON. That would be a very helpful contribution on your part. We do not intend to break for lunch.

Mr. BUSH. And in most instances, Senator, my remarks are going to paraphrase the report and the report should be used only as a reference document for refreshing your memory on some of the things that I might say.

You will hear several times the dissertations in these 2 days of how nuclear research has reduced the cost of power and that the

Government has spent billions on this kind of research along with industry and you will also hear that desalted water used to cost \$6 per thousand gallons and now costs less than \$1 per thousand gallons so that the logical thought process is that if the Government spends enough the cost of water must come down.

I think there is more to it than this. The cost of water, desalted water, must be cut significantly under where we are now and you have brought out the point that no one even discusses the cost of irrigation water from a desalting process, but I think that if one addresses himself to what industry has done over the years, mainly with its private funds in our basic, more prosaic industries, he would have the confidence that the cost of desalted water is going to come down and particularly with the benefits derived of a joint program of both Government and industry financing the developmental work and the building of large plants.

The report you have shows many of the examples over the last 30 or 40 years and particularly, those examples with which the firms I represent are quite familiar because they are in the same business.

The report shows cost indicators for aluminum, cement, gypsum, magnesium, power, and steel production. These cost reductions and manpower reductions are simply the result of technological change and equally important, the scaleup from very small plants.

For instance, the aluminum cells designed in 1942 used 32,000 amperes. Now, we are designing plants for 150,000 amperes and the unit aluminum production from such a reduction cell is almost in direct proportion. The aluminum industry as a whole, in 1949, required 14 man-hours per thousand pounds of product. Now it is less than half of this.

The steel plant as recently as 1957—and mind you this is a mature, a very mature industry—the steel plant with which I am familiar required 6.8 man-hours per thousand pounds. It is now down to less than 5 in just a short 8 years.

How does this come about, you will ask. It comes about because of certain developments such as the carbon refractories in the blast furnace; use of oxygen in open hearth, and new oxygen steel processes developed.

How does this relate to desalted water? These are all processes just like the desalination of water is a process and the incentive of private industry with the help of Government development can only bring these things about.

In the plant we have for winning magnesium from salt water, sea water on the Pacific coast, our through-put of that plant is increased from 2 billion gallons a year to 9 billion gallons per year. We are basically the same plant. The man-hours required for this has dropped from 5 man-hours per thousand pounds of product in 1949 to only one and a half. Large kilns, more rapid thickeners, larger thickeners—in other words, the power industry required 2 pounds of coal per kilowatt-hour in 1925. Another very, very mature industry, and yet, since that time, our most modern plants are under seven-tenths of 1 pound of coal per kilowatt-hour. The trend is down, but the important thing here is that these trends, financed mostly with private industry funds, have been slow as funds were made available.

The important thing here is that for desalted water we cannot stand the pace, even though by some peoples' estimate the pace might have been rapid in private industry.

This is a vital thing and it must be a team effort between Government and private industry. A similar case is atomic energy, electronics, and space. What could be more vital than water? There are those who will tell you leave it to them—we will build you these big plants. We are prepared to guarantee them, they will say, but when you analyze the guarantees if the prices are anywhere near what one considers to be a reasonable price, in most cases they are based upon an unreasonable set of assumptions such as very high plant factors, very, very low fixed charges, and other conditions which then come out to 60 or 70 cents per thousand gallons, maybe 40 cents. We have even heard the numbers of 30 and 35 cents per thousand gallons. Not even the unbridled enthusiasts are guaranteeing anything competitive right now for domestic water supplies throughout most of the water-short areas, and also no one even discusses irrigation where the cost must even be one-fourth of that for domestic usage.

I can well remember in my business 10 years ago, the one I am most familiar with—we had some enthusiasts who were talking about 7 mill power from nuclear energy. There were those who got up at our atomic industrial forum meeting, the American Nuclear Society meeting, and said 7 mill power from nuclear plants is here and now, but it will be 1968 before we get the first plant now in real life. After billions of dollars of research, we are now there and the plants come on the line in 1968.

Of course, there has been a moving target in that which has helped with competitive conditions. Now, if the foregoing remarks on the rate of progress are true, then why should we build any medium sized and large plants one might ask. Why should we not just stay with the small development work? Well, it is not that way or that easy because the examples that are cited in the normal, basic industry carry over into desalting of water also. One gets only so far with basic development work, but you must build the medium- and large-scale plants in order to accomplish what you are after.

The developments are obvious, but there is a synergistic effect which comes from building a large-scale plant and in most of our industrial work, not simply related to desalting, one gets these benefits when he builds the large plants. Also, it gives you the opportunities of comparing two or more alternates in a large plant because you can afford to put two differences into a plant and test them.

Recovering polluted water, in my opinion, is not the answer to this problem because, unfortunately, most of the cases where we have polluted water, there are reasonably ample water supplies.

It is in the water-short areas where there is no industry and no polluted water where we are most concerned about the future.

One further point: It is axiomatic when natural resources are being depleted that any incremental use of that resource must come at a higher price. Whether it is fuel or copper or iron ore, the same thing is true. The depletion process begins and the increment required, particularly in this country, to keep pace with our increased standard of living and our exploding population must cost more and when it costs more on the average, the standard of living is lowered unless there is a

development of technology and scale-up in plant size or importing of cheaper material.

The development of technology and scale-up of plant size has already been discussed, but as far as importing water is concerned, there are a couple of items that cause concern. One is that it is most difficult to stockpile like other strategic materials. There is also no substitute for it as we were able to accommodate substitutes during the last war and furthermore, the plans for bringing in Alaskan and Canadian water supplies are being projected 30 to 50 years in the future and this is not a criticism of that; it is a tremendous project and even the enthusiasts for that kind of a plan are not sure that the cost will really be any less than what desalination would cost.

I do not think this country should take its chances on holding off on the development of desalted water technology in the hopes that the long-range plans for Canadian and Alaskan water would come through in time.

The interesting thing is that the water shortage, while having the most publicity in the West, really has come to many other parts of our country as well.

Who would have dreamed that Long Island would be interested in a desalting program?

In summary, then, it is fitting that the pace must be increased and the only way I know of to do this is a partnership between Government and industry to pursue the developmental work and the building of medium- and large-scale plants together.

Thank you very much, Senator.

Senator ANDERSON. Thank you, Mr. Bush, for a very fine statement. We will have a chance to review your remarks and your report. Your prepared statement will be inserted at this point in the record. We do appreciate the fact that you did condense your statement.

Thank you very much.

(The prepared statement referred to follows:)

STATEMENT OF PHILIP D. BUSH, VICE PRESIDENT, KAISER ENGINEERS, DIVISION
OF KAISER INDUSTRIES CORP.

Mr. Chairman and members of the subcommittee, my name is Philip D. Bush. I am vice president of Kaiser Engineers Division of Kaiser Industries Corp., with headquarters in the Kaiser Center, Oakland, Calif. I have been actively engaged in plant operation, process engineering, and construction for 26 years, of which 22 years have been with the affiliated Kaiser companies. Specific experience has encompassed the following industries: steel and its byproduct chemicals, aluminum, cement, gypsum, metal products, nuclear energy, space, and desalination.

My purpose in appearing before you is to bring to your attention examples of how U.S. industry, by increases in equipment and plant sizes and/or technological changes, has been able to increase productivity and reduce unit costs dramatically. In some cases, this has been brought about by startling technological breakthroughs, but in most cases the results have been obtained by a series of significantly large "stepwise" increases in size or a combination of several process improvements. The statements which follow include actual examples of the above ideas as they pertain to those industries in which the author is well versed.

INTRODUCTION

Kaiser Engineers, serving as engineer-constructors to the Kaiser-affiliated companies, and worldwide industry as well, has contributed to and is familiar

with the means by which the basic raw materials, process, and manufacturing industries have effected unit cost reductions by means of technological change and increased plant or equipment capacity.

Kaiser Industries Corp. includes among its affiliated companies producers of aluminum and refractories, steel, cement, and gypsum. These industries require the chemical processing of billions of pounds or gallons per year of naturally occurring raw materials. Kaiser Aluminum produced over 1 billion pounds of product, Kaiser Cement & Gypsum produced over 7 billion pounds of product, and Kaiser Steel nearly 5 billion pounds of product in 1964.

The Refractories Division of Kaiser Aluminum & Chemical Corp. in 1964 processed 30 million gallons of sea water per day for recovery of magnesia for refractories.

In these basic industries the history of the manpower used, process improvements made, and increases in component, module, and plant capacity, and their effect on product cost may be used as a basis for predicting the future trends of the desalting industry.

For example, the maximum size grinding mills in the cement industry in 1955 was 1,500 horsepower. Larger size mills may have been more economical in 1955, but no one knew how to design and build them. An intensive development program has now raised the maximum size of this important component to 6,000 horsepower. The amount of capital cost saving per barrel of capacity and increase in grinding efficiency are impressive.

The nuclear power industry is another example where technological improvements have produced recent startling results. The past 2 years have changed the competitive nature of fossil-fuel and nuclear-fueled plants. Oyster Creek, Dresden No. 2, Niagara Mohawk, and Los Angeles Malibu are new powerplants using nuclear energy rather than fossil fuel on the basis of economics.

These examples illustrate the kind of data I believe are pertinent to desalting. While the interaction between manpower reductions, process improvements, increases in plant capacity, process efficiency, and technological advancement is complex, a look at the separate categories reveals the gains which have been made and indicates those which are possible in related industries.

I have chosen to present the data on aluminum and refractories, steel, cement, gypsum, and nuclear power in four sections:

Section I tabulates the manpower required per thousand pounds of product (which represents one component of product cost), and discusses how some of these gains were made.

Section II gives specific examples of process improvements in these industries showing the effect each has had on the cost of the product. These improvements are rarely foreseeable or predictable exactly as to timing or magnitude. They occur in both new and well-established industries; they can be expected in a fast moving industrial technology.

Section III lists the history of unit energy consumption in several of these industries, this being an important element of product costs affected by advancing technology.

Section IV shows the dramatic effect of module size changes in the cement industry, electric utility industry, and steel industry, and the effect they have had on capital costs.

These four sections present data representative of basic industries processing large quantities of bulk raw materials—industries whose process philosophies are similar to those of an industry devoted to desalting water.

SECTION I. TRENDS IN MANPOWER REQUIRED TO MANUFACTURE VARIOUS PRODUCTS

At the turn of the century, aluminum was an infant industry producing small quantities of a high-priced product. The early history of the price per pound and the annual production of the aluminum industry is a good example of how production quantity and costs are related as an industry matures. Table I illustrates the marked early price reductions, and the continuing increase in annual production which occurred. The data spans 60 years during which time there were many business cycles and external economic changes, yet the data shows an overall downward trend in costs.

TABLE 1.—*History of aluminum primary ingot prices*

Year	Price per pound	Annual production (1,000 tons per year)
1886	\$8.00	
1889	2.00	
1893	.75	2
1918	.33	60
1925	.28	70
1930	.24	110
1935	.21	40
1940	.20	180
1945	.14	600

Table 2 shows the manpower requirements per thousand pounds of product. Even in such mature industries as those listed, reductions are still taking place. For instance, the figures for aluminum show a 50-percent reduction in the 12-year period between 1950 and 1962.

A specific example, Kaiser's Baton Rouge plant processes bauxite into alumina (the basic aluminum oxide from which aluminum is produced) using huge quantities of steam and soda in chemical digesters.

TABLE 2.—*Trends in manpower requirements to manufacture various products reductions result from increased equipment and plant sizes as well as from process technology changes*

[Units are man-hours per 1,000 pound of product]

Year	Alumi-num industry average (Alumi-num)	Kaiser Aluminum & Chemical Corp.		Kaiser Cement (cement)			Kaiser Steel (steel, Fontana, Calif.)
		Alumina, Baton Rouge plant	Magnesia, Moss Landing, Calif.	Plant A	Plant B	Plant C	
1949	13.9		2.6				
1950	12.7						
1951	13.1						
1952	13.3						
1953	13.6						
1954	12.1		1.1				
1955	10.8	2.3					
1956	10.3						
1957	10.2						6.8
1958	8.9			0.50			6.4
1959	7.7		.7	.50			5.6
1960	7.2			.50	0.37		6.4
1961	6.9			.50	.37		5.4
1962	6.6			.50	.37		5.6
1963				.25	.37	0.30	5.0
1964		.9		.25	.37	.30	4.5

Source: U.S. Department of Commerce.

The manpower requirements at Baton Rouge have been reduced by 60 percent in the last 9 years as shown in column 3 of table 2. This was accomplished in a 20-year-old plant by process improvements such as raising the digester temperature to 400° F., increasing the capacity of some components and by making a modest increase in plant capacity. More economical forms of caustic soda are now used; a substitute has been developed for cornstarch and a new source of lime has been developed. These process improvements and corresponding manpower reductions have resulted in almost a 50-percent reduction in the cost of producing alumina.

Kaiser's magnesia plant may be of even more interest because of the use of sea water as a raw material. As Moss Landing, Calif., Kaiser refractories operates a plant to produce magnesia and periclase, materials which are used primarily in the manufacture of basic refractories. Since the plant was built in 1942, a number of major additions and improvements have been made. Column 4

of table 2 shows the steady decline in man-hours worked per 1,000 pound of plant production for 5-year intervals.

The Kaiser cement data illustrates the result of technological advances made as new plants are built. Plants A, B, and C are three Kaiser cement plants built in sequence 2 or 3 years apart:

1. Each of these plants was initially designed for the same capacity, but the man-hours required per pound of cement have been reduced by 40 percent between 1958 when plant A was built and 1963 when plant C was built.

2. At plant A the capacity was doubled in 1963 by an increase in grinding mill size from 2,000 to 4,000 horsepower per mill, and an increase in kiln size from 12 feet diameter by 450 feet long to 16 feet diameter by 520 feet long. The only increase in men needed was 5 percent for quarrying and shipping.

3. Plants B and C are the same capacity but reduced manning requirements reflect technological improvements such as better layouts and centralization of equipment control.

	Plant B (built 1960)	Plant C (built 1964)
	<i>Men</i>	<i>Men</i>
Quarry including crushing.....	11	7
Mills, kilns, plant labor.....	26	16
Mechanical and electrical maintenance.....	14	16
Total.....	51	39

Table 2 also shows the reduced manpower for Kaiser Steel's plant at Fontana, Calif. Kaiser's process improvements which are typical of those within the steel industry include many items described in the next section, but the effect on man-hours per thousand pounds of finished steel is a good measure of the continuing process improvements and equipment modifications still taking place in one of the oldest of industries.

SECTION II. PROCESS IMPROVEMENTS IN SPECIFIC INDUSTRIES

A. Aluminum production

Kaiser Aluminum & Chemical Corp. is a fully integrated producer of primary aluminum and fabricated aluminum products. Since Kaiser Aluminum entered the aluminum business in 1946, it has made significant progress toward lower costs through innovation, technological change and size scale-up of various unit operations.

Aluminum ore, called bauxite, consists of alumina, present as a hydrated oxide, together with various impurities. The reddish bauxite ore, mined by open pit operations, is shipped to alumina plants where it is refined into pure granular aluminum oxide (alumina).

The alumina is then dissolved in molten cryolite (sodium aluminum fluoride) contained in shallow, carbon-lined steel tanks known as reduction pots. As electric current passes through the alumina-cryolite bath, the oxygen of the alumina combines with the carbon lining, molten aluminum is produced and collects in the bottom of the pot. The molten aluminum is periodically siphoned off and poured into molds to form ingots.

Kaiser Aluminum fabricating facilities roll, forge, and extrude the basic metal into a variety of products, which are distributed nationally and internationally to industrial and certain consumer markets.

Alumina.—In 1949, Kaiser acquired the Baton Rouge alumina plant which originally was designed to handle high-grade bauxite of the trihydrate type. These trihydrate bauxites were generally expensive to mine and ship and their occurrence and ownership were quite limited. During the period from 1948 through 1953, Kaiser explored and developed deposits of Jamaican bauxite as a major source of raw material.

The standard trihydrate (Bayer) process, which is used in this country for refining Surinam (Dutch Guiana) bauxite, was unsuitable for processing the mixed monohydrate-trihydrate Jamaican bauxite because of the appreciable losses in the form of unextracted monohydrate alumina. Kaiser modified the Baton Rouge plant to handle the Jamaican bauxite. This involved a novel process with higher operating temperatures, pressures, and flows, and resulted in greatly reduced alumina costs for Kaiser.

In 1955-56, further process improvements were made in the design of the alumina plant at Gramercy, La., to process Jamaican bauxites even more efficiently. Temperatures were raised to 470° F. (compared with 300° F. for the original Baton Rouge design and 400° F. for the Baton Rouge plant after modification). Special large valves and piping systems were developed. The Gramercy plant was the largest single-unit alumina plant ever built when completed. The new Gladstone, Australia, plant of Queensland Alumina, Ltd. (jointly formed with three other participants in which Kaiser Aluminum owns 52 percent), will be even larger, continuing the trend.

To see the effects of these technological improvements, let's take the Baton Rouge plant as an example. In 1955, the plant employed a work force of 1,800 people to produce 830,000 tons per year of alumina. The same plant today makes 940,000 tons per year, while the work force has been reduced to less than 800 people. Ground sorghum has replaced refined cornstarch as a settling aid; liquid caustic soda has taken the place of dry soda ash as a raw material; lime is produced from raw oyster shells dredged from Lake Pontchartrain. Alumina costs from today's most modern plants are only one-half to two-thirds of costs per ton 10 years ago.

Aluminum reduction.—The trend in reduction cell design has been toward higher amperage operation with consequent increases in the physical dimensions of the cells. At the same time, advances in operating techniques and designs have led to more efficient cell layouts with the result that the production per unit floor area has increased markedly.

The design of a reduction cell is complicated by numerous hardware problems (anode clamps, electrical connections, jacking mechanisms), selection of proper materials of construction for cell linings and collector bars, and unknown magnetic effects. As a result, progress from smaller to larger cell designs usually follows the slow-and-steady route of relatively small changes followed by periods of operation during which the "bugs" are worked out. However, the rate of change is increasing, as evidenced by the following Kaiser Aluminum experience:

A. Cells using Soderberg-type anodes

Plant	Year	Cell electric current amperes
Tacoma, Wash.:		
Original design.....	1942	32,000
1st modification.....	1947	38,000
Experimental addition.....	1952	55,000
Chalmette, La.:		
Original design.....	1950	64,500
Modifications.....	1965	71,700

B. Cells using prebake-type anodes

Plant	Year	Cell electric current amperes
Mead, Wash.:		
Original design.....	1942	50,000
Gradual improvements (increased cells per line from 130 to 140 and added 2 lines).....	(1)	(2)
Ravenswood, W. Va.:		
Original design.....	1957	78,000
Modifications.....	1965	86,500
Volta Aluminium Co., Ltd.: Design and prototypes.....	1965	150,000

¹ 1946 to present.

² Up to 64,500.

Along with the increases in the size of each cell have come increases in the number of cells per line and lines per plant, which also have the effect of lowering unit capital and operating costs. These improvements have generally held the primary metal production cost steady in the past 10 years in spite of increases in labor, materials, and energy costs.

Raw materials.—A third area in which primary aluminum producers have been able to reduce or stabilize costs is in raw materials and process supplies. Efforts here fall into several broad categories:

1. Utilization of waste materials—an example is the use of fluosilicic acid waste from the Florida phosphate industry as a raw material for cryolite.

2. Replacement of higher cost with lower cost materials—for example, use of ground sorghum instead of refined cornstarch has reduced operating costs by \$1 million annually.

3. Integration of raw materials manufacture with primary processing where attractive purchase arrangement cannot be made. An example is Gramercy where the boilers required for steam production for the alumina plant run extraction turbines which produce power for a caustic-chlorine plant on the site. (Caustic soda is a principal raw material in the manufacture of alumina.) An intermediate stream from the alumina plant is used to make aluminum fluoride, used in the reduction process. The chlorine from the caustic-chlorine plant offers several future possibilities for chemicals expansion. Hydrogen fluoride generated from the aluminum fluoride plant is used to produce fluorocarbons.

Effect of mechanical changes.—Table 3 lists a few examples of mechanical changes which have been made in aluminum fabrication. The tabulation indicates the way in which process improvements and modifications steadily increase production and reduce costs.

TABLE 3.—*Effect of mechanical changes on operation capacity*

Description of operation	Mechanical changes	Percent capacity increase
1. Aluminum wrought ingot is remelted for alloying and casting into sheet rolling ingot in a typical size of 16 by 44 by 112 inches.	Replaced square remelt furnaces having side loading charging machine with round furnaces having removable tops for crane handled charge bucket loading. Melting and casting can be performed simultaneously.	+15
2. Sheet rolling ingot is scalped by planing the 44- by 112-inch surfaces prior to hot rolling operation.	Mechanized scalping operation to achieve a programmed machine controlled operation and eliminated a remote chip baling operation.	+8
3. Hot rolled coil is further reduced in gage by cold rolling operations.	Replaced 3 to 5 individual cold mill operations on conventional 1 or 2 stand cold mills with a 5 stand cold mill operation which eliminates coil changes between cold mill stands.	+17
4. Extrusion billet, which is cylindrical in shape, is loaded into the extrusion press container for extruding into various shapes by pushing the heated aluminum through a die.	Automation of the billet loading and butt cut off and removal reduced the press dead cycle time.	+11
5. Cable stranding from wire.....	Redesign of stranders to handle larger diameter bobbins.	+13

B. Refractory industry

Kaiser Refractories, a division of Kaiser Aluminum & Chemical Corp., is a completely integrated producer of acid and basic group refractories.

One common type of refractory is made from periclase (a dense crystalline form of magnesia) and chrome ore. Large tonnages of this refractory are used for lining open hearth and electrical steel-making furnaces, the high temperature zones in cement and lime kilns, glass furnace regenerator systems, copper reverberatory furnaces and converters, and a variety of specialized applications.

The principal sources of raw materials for making periclase are natural magnesite (magnesium carbonate), dolomite (calcium magnesium carbonate), sea water, and brine. The process starts with dolomite rock which is quarried, crushed, screened, and calcined in rotary kilns to remove carbon dioxide. Calcined dolomite and pretreated sea water are brought together in huge tanks where a reaction takes place forming magnesium hydroxide.

After thickening and filtering, a thick paste of highly pure magnesium hydroxide is fed into rotary kilns along with carefully controlled additives. The resulting product, periclase, is highly refractory and will not appreciably change

in size when subjected to further heating. In inland areas, brine from deep wells is utilized for making periclase.

At Moss Landing, Calif., Kaiser Refractories operates a plant to produce magnesia and periclase, materials which are used primarily in the manufacture of basic refractories. The plant digests calcined dolomite with softened sea water in a reactor to produce magnesium hydroxide. After thickening and filtering, the hydroxide is burned, together with certain additives, to produce magnesia, usually in the form of periclase. The spent sea water is returned to the sea.

Since the plant was built in 1942, a number of major additions and improvements have been made. The time and man-hours required to produce a ton of material has shown a steady decline. The table on the following page shows, at 5-year intervals, the relation between man-hours worked and capacity. Also shown, as a measure of the increase of capacity, are the billions of gallons of sea water processed per year.

Year	Tons capacity per year	Man-hours per year	Man-hours per ton of capacity	Gallons of sea water processed per year
1949	31,200	164,000	5.25	2,309,000,000
1954	79,780	170,000	2.13	5,904,000,000
1959	126,580	186,000	1.47	9,367,000,000

When the plant was built in 1942, it had one rotary kiln. The capacity was more than doubled when a second and larger rotary kiln was added in 1950. With the increased capacity in 1954, only a few additional man-hours were required. In 1957, another major change was completed with the addition of a third kiln and other major improvements and expansion in the reaction and thickening systems.

C. Cement and gypsum

The principal production operations carried out by Kaiser Cement & Gypsum Corp. include the manufacture of portland and special cements, plaster, gypsum wallboard, lath, and sheathing.

Cement.—Cement production facilities are located in the States of Washington, California, and Hawaii and have a combined capacity of over 7 billion pounds per year of cement. Limestone, clay, and raw gypsum are the principal raw materials used in cement production. The limestone, a form of calcium carbonate, is quarried, crushed, and ground in a series of grinding operations. After a screening process, the pulverized limestone is pumped in a water suspension to blend tanks, where clay, iron ore, and other elements are added. The agitated "slurry" is fed into revolving kilns which burn the slurry mixture at 2,700° F., producing white-hot clinkers. The clinkers are cooled and pulverized in ball grinding mills. Raw gypsum is added, in varying amounts, prior to the grinding operation to control the setting time of the cement.

The initial plant, built in 1939, employed the largest equipment known to the industry at that time.

The company's second plant, built at Cushenbury in California's Lucerne Valley in 1957, was outfitted with 1,500-horsepower mills, the largest grinding mills then available. During the 1962-63 expansion the plant was equipped with the West's largest kiln, 16 feet diameter by 520 feet long, and the biggest cement grinding mill in the world, 4,500 horsepower. These giant facilities doubled the plant's capacity with no increase in work force and with striking capital cost benefits. At the same time the larger kilns required 7 percent less fuel per unit of production.

Gypsum.—Gypsum plaster and wallboard are made in several locations of Kaiser Gypsum Co., Inc. Raw gypsum ore is the principal raw material for the production of plasters, gypsum wallboard, lath, and sheathing. The ore, a chalk-like rock of calcium sulfate dihydrate, is quarried, crushed, and ground to a fine powder. The powder is calcined at a temperature of 250-350° F., which drives out approximately 75 percent of the chemically combined water. The resulting calcium sulfate hemihydrate is reduced to microscopic flakes in a rotating tube

mill, partially filled with steel balls. This improves the "stucco's" plasticity, aging properties, and workability when used as plaster.

After ball milling, the "stucco" is combined with retarder and other dry ingredients to produce plaster, which is sacked by high-speed machines.

For gypsum board products the "stucco" is mixed with paper pulp, foam (to decrease the product density), starch, and water to form a thick slurry. The slurry is discharged onto an unreeling roll of manila paper. Over this goes gray back paper to form a sandwich. The continuous gypsum board sandwich moves on belts and rollers along huge boardmaking machines. The long sandwich is cut into lengths at the end of the board line and dried.

Each of the four existing gypsum products plants is designed for efficient, straightline production. The plants have been continually modernized, resulting in increased instrumentation and centralized process control. The new Jacksonville plant incorporates the latest steps toward automation.

Specific examples of process improvements in Kaiser Gypsum plants are shown in table 4.

TABLE 4.—*Specific examples of process improvements, Kaiser Gypsum Co., Inc., 1960-64*

<i>Process improvements</i>	<i>Effect on process (reductions in cost of 1,000 square feet of wallboard)</i>
1. A method was found for substituting a waste material for a purchased raw material-----	\$0.20
2. An improvement was made in the method of winding and handling paper rolls-----	.07
3. A dry weight reduction was made possible by improved additions and product control-----	.12
4. A kettle was automated resulting in increased production-----	.03
5. An improvement was made in the handling of pulp used in the gypsum board core-----	.20
6. The 1st zone of the dryers was changed from steam heated to direct gas fired, permitting faster drying-----	1.30
7. An improvement in instrumentation to produce more uniform thickness-----	.03

D. Steel industry

Kaiser Steel Corp. is a fully integrated producer of rolled and fabricated steel; i.e., it mines the ore and coal, and smelts the ore into pig iron and makes and processes steel for sale. The company's steel mill at Fontana, Calif., has been under almost continuous expansion since its initial facilities were built in 1942.

The basic raw materials used in steel production—iron ore, coal, and limestone—are supplied from the company's western mines and quarries. The ore, which averages 42 percent iron as mined, is upgraded (beneficiated) to 60 percent before shipment. The coal is processed into coke in coke ovens.

The beneficiated iron ore, coke, and limestone are fed into the top of the blast furnaces by skip cars. The furnaces smelt the raw materials and reduce them to molten pig iron and slag. At intervals the iron is tapped from the pool of hot metal formed in the hearth of the furnace and is transferred by a "torpedo" car to the steelmaking furnaces.

The molten pig iron is then fed into steelmaking furnaces along with steel scrap and other materials, under close quality control, and converted into steel. These steelmaking furnaces are of two types, those using the open hearth method and those using the L-D process, a basic oxygen steelmaking technique. After the steel is tapped, it is poured into molds to form ingots from which, after a brief cooling period, the molds are stripped and the ingots placed in soaking pits until moved to the rolling mills.

The first step in rolling takes place in either a stabbing or a blooming mill where the large preheated ingots are rolled into smaller and more easily handled shapes called slabs or blooms. From this primary rolling stage, the steel is distributed among the Fontana plant's nine other rollings mills for finishing to final shape, e.g., sheet, pipe, structural bars, tin plate.

High grade iron ore for Fontana's blast furnaces comes from the company's mine at Eagle Mountain, Calif. The ore is mined in huge open pit operations in which overlying rock is stripped to expose the ore. The beneficiation plant upgrades the ore by separating waste materials and low-grade ores from the higher grades to increase the iron content. The production and iron content of

the ore shipped from the beneficiation plant has been upgraded by a series of process additions and improvements. In 1953, the annual beneficiated ore production was 1.8 million tons with an iron content of 55 percent. In 1954, heavy media and dry magnetic separation was added for more beneficiation; in 1955, a jig plant; and in the 1961-63 period, a wet magnetic separation process was added and further crushing, blending, and mining improvements were effected.

Each of these process improvements has resulted in a higher grade ore for input to the Fontana blast furnaces. In 1964, production increased to 5.2 million tons/year with a 60-percent iron content. At the present time, a new pelletizing plant is under construction. The pelletizing plant will be equipped with the world's largest pelletizing machine. Though a basic magnetite, the concentrate contains 20 to 50 percent hematite, necessitating a flexible process to yield consistently good pellets from a varying concentrate. Pellet drying, firing, and cooling will all be carried out in one piece of equipment.

The potential pig iron production from the four Fontana blast furnaces has increased during the last 7 years from a total of 5,800 net tons/day in 1957 to 6,950 net tons/day in 1964 (a 20-percent increase). Again a key factor in this production increase has been the improvements effected in iron ore beneficiation. This has resulted in a higher iron content in the ore fed to the blast furnaces, less gangue (or mineral contaminants), and better burdening of the ore. Due to the reduced gangue content in the ore, the volume of slag has been correspondingly reduced. Another process improvement, which has resulted in increased potential production, has been the replacement of refractory brick linings with carbon linings. This has increased the effective volume of the blast furnaces.

The older method of steelmaking is by the open hearth process. The open hearths are low, rectangular, stationary brick structures with a furnace interior shaped like a shallow dish. Limestone, steel scrap, and molten pig iron are charged through water-cooled doors in the front. The production capabilities of the Fontana furnaces have been considerably enhanced by oxygen enrichment. The first improvement was the use of oxygen in the end wall burners. This increased the average capacity from 21.9 ingot tons/hour to 28.5 ingot tons/hour, an increase of 30 percent. The most recent innovation has been the use of an oxygen lance through the furnace roof. This has further boosted the average production to 36.1 ingot tons/hour, another increase of 26 percent.

TABLE 5.—*Specific examples of process improvement, Kaiser Steel Corp., Fontana, Calif.—Period 1957 to 1964*

Item—blast furnaces	Improvements	Effect of process change
Coke rate.....	Improved ore quality; natural gas injection; self-fluxing sinter; increased air temperature.	24 percent reduction.
Hot metal potential production.....	Improved ore quality carbon linings...	20 percent increase.
Open hearth steelmaking furnace:		
Average daily production.....	Oxygen in end burners..... Oxygen lance through roof.....	30 percent increase. 26 percent increase.

SECTION III. ENERGY CONSUMPTION TRENDS

The electrical utility industry in the United States is a clear example of reductions of the cost of a utility service resulting from technological improvements. Part of the reductions in electric power costs have been improvements in the powerplant cycles due to higher temperatures and pressures, made possible by advances in metallurgy and process design. Larger size units have also been important in reducing unit costs and these again have required stronger steels for turbine rotors, new turbine blade designs, and improved boilers. The resulting improvements in efficiency are reflected in the remarkable reduction of pounds of coal used per kilowatt-hour generated and are shown in table 6.

TABLE 6.—*Fossil-fueled powerplants*

Year:	Pounds of coal per kilowatt-hour	Year—Continued	Pounds of coal per kilowatt-hour
1925.....	2. 029	1957.....	0. 928
1930.....	1. 596	1958.....	. 904
1935.....	1. 439	1959.....	. 890
1940.....	1. 340	1960.....	. 876
1945.....	1. 302	1961.....	. 863
1950.....	1. 189	1962.....	. 858
1955.....	. 954	1963.....	. 856
1956.....	. 935		

The cement industry and steel industry have made similar improvements in energy consumption. The improvements in efficiency in the cement industry are primarily due to increases in kiln size and grinding mill size. The 16-foot diameter by 520-foot-long kilns require 900 cubic feet of natural gas per barrel of cement produced, whereas the 12-foot diameter by 450-foot-long kilns being built in 1957–58 required 1,200 cubic feet of natural gas per barrel produced.

The cement industry has also reduced unit electrical energy consumption by increasing the grinding mills from 9.6 feet diameter to about 15 feet diameter. Milling efficiency increases with increasing diameter. A 20-percent energy reduction has resulted from this change.

In the steel industry one of the most important cost factors in blast furnace operation is the coke rate (pounds of coke consumed per ton of iron smelted). At Fontana the coke rate has been reduced from 1,490 pounds per ton in 1957 to 1,130 pounds per ton in 1960, a 24-percent reduction within a 7-year period. This has been accomplished through several process improvements:

- (a) Beneficiation improvements in ore quality.
- (b) The use of self-fluxing sinter.
- (c) Natural gas injection.
- (d) Increasing the temperature of the air supplied to the blast furnace.

A portion of these energy gains in the electric utility, cement and steel industries has been accomplished by going to larger sizes. But the increase in efficiency is only a part of the gains in scale up. Gains in capital cost per unit of production may be expected. Section IV describes the effect of scale up.

SECTION IV. SCALE UP IN COMPONENT AND PLANT SIZE

The reduction in capital costs per unit of production is a commonly expected benefit from increased size.

The electric power industry has made great cost reductions by going to larger unit capacity in the fossil fuel installations and is now making greater gains in the nuclear power field. These scale-up, unit-cost factors are shown in table 7. Also shown in this table are the bus-bar energy cost for the nuclear plants: a true measure of overall cost of producing power.

TABLE 7

Megawatts capacity	Station-fossil fueled ¹ capital cost (dollars per kilowatt)	Station-nuclear fueled ² capital cost (dollars per kilowatt)	Cost of power (mills per kilowatt- hour)
60.....	195.....	{ 1,222 (Shippingport)..... 325 (Pathfinder).....	} 60. 15
75.....	188.....	.....	.....
100.....	172.....	.....	.....
150.....	155.....	.....	.....
175.....	.....	224 (Yankee).....	11. 0
200.....	.....	183 (Dresden No. 1).....	9. 0
300.....	140.....	.....	.....
500.....	130.....	{ 180 (Nine Mile Point)..... 132 (Oyster Creek).....	6. 67 4. 25
1,000.....	128.....	.....	.....

¹ Electric World, Oct. 7, 1963, "12th Annual Steam Station Cost Survey."

² Electric World, May 1964, "9th Annual Nuclear Power Report."

The cement industry is benefiting from scale-up factors both in component size and in overall plant capacity. The grinding mill cost per unit of capacity is shown in table 8. The scale up of grinding mills, it should be pointed out, is the result of extensive development. In fact the scale up of modules, components, and whole plants in most industries requires a developmental program to determine how to design the larger equipment.

The cost trend of scaled-up cement plants as a whole follows the trend of the grinding mills as shown in the companion table.

TABLE 8

Cement plant capacity, million barrels per year	Ratio, grinding mill cost per unit of capacity	Ratio, plant cost per unit of capacity
1-----	100	100
2-----		84
3-----		74
4-----		68
5-----		
6-----	68	
7-----		
8-----		60
9-----	60	60

The scale-up effects in the iron ore mining area include increasing the capacity of shovels and trucks. Kaiser's Eagle Mountain Mine uses a variety of capacities and the operating costs per unit of capacity show the scale-up advantages.

	<i>Ratios, operating cost per unit capacity</i>
Truck capacity :	
40 to 65 tons-----	100
100 tons-----	60
4.5 to 5 cubic yards-----	100
8 cubic yards-----	60
12 cubic yards-----	50

CONCLUSIONS

In summary I have tried to show four areas of cost improvements in the process industry :

(a) The trends of lower man-hours per 1,000 pounds of product—a trend downward in four basic industries.

(b) A series of stepwise process improvements, some resulting in large cost savings, and nearly all associated with increasing the capacity of a plant component or module. Increased temperature, higher flows, better control of chemical treatment, and more efficient equipment were all significant in these gains.

(c) The trends in reductions of energy consumption, more product per pound of fuel, and use of larger and more efficient equipment (ranging from ball grinders to shovels and trucks to kilns and turbines).

(d) The unit capital cost reductions associated with scale-up, and the developments which are necessary to be able to scale up the designs.

These four areas are interrelated and complex. Increased efficiency will lower energy costs and capital costs may reduce manpower and may make a previously uneconomical process competitive.

An example of the above interrelation is dramatically shown by the dual-purpose Volta River Hydro Electric-Volta Aluminum Co. Ltd., project in Ghana, West Africa. Modern engineering and construction technology have made the Volta River Dam feasible. This 10-million-cubic-yard rockfill dam 370 feet high and with a 2,100-foot crest length and associated hydroplant will cost about \$180 million and produce 768 megawatts of power. A 67-mile-long, 161-kilovolt transmission line will supply this power to local industries and for aluminum manufacturing.

The availability of low-cost power and African aluminum-bearing ores are responsible for the feasibility of the aluminum reduction plant now being built. The reduction plant will cost about \$128 million and has a first-stage annual capacity of 100,000 tons of aluminum.

The availability of low-cost power and aluminum may trigger still more interactions of industrial processes.

What are the cost-reduction chances for the desalting process? The proper answer is not a guess but a projection of the history of basic industries: process improvements, developing ways to increase capacities of modules and components, reducing energy consumption, and increasing module size. These have resulted in the past from higher temperature operations, lower cost power, larger equipment, and improved process control. Also, process improvements have come about from new steel furnace and blast furnace liners, larger trucks and materials handling equipment, larger and more efficient grinding mills, and finding substitute lower cost materials to accomplish the same purpose.

The desalting counterparts may be better scale control, higher brine heater temperature, lower cost waste heat from nuclear dual-purpose plants, higher capacity modules, and new feed water treatment methods. We can also expect lower unit costs with plastic coatings for concrete or new concrete formulations, larger and more efficient pumps and perfection of the use of sea salts in "seeding" for scale control or for new industrial or agricultural uses.

Development of many of these improvements will take time and their interrelation in the process complex, but until demonstration plants first and then increasingly large plants are built and operated, the true effects will not be realized. One thing is certain—with the advent of these plants, the reductions in the cost of desalted water will follow the same dramatic and inexorable path still being experienced in other and older basic industries.

Mr. Chairman, I thank you for your attention and this opportunity to appear before you and members of the subcommittee.

Senator ANDERSON. Our next witness is Mr. Clifford Sandland, of the C. F. Braun & Co., of Alhambra, Calif.

Mr. Sandland, I want to assure you I am a little worried about this document also. I hope you will condense it if you can.

STATEMENT OF CLIFFORD SANDLAND, C. F. BRAUN & CO., ALHAMBRA, CALIF.

Mr. SANDLAND. I, too, have condensed the prepared statement to something in the order of 10 minutes, Mr. Chairman.

Senator ANDERSON. I will make the same statement as I did to Mr. Bush, that if subsequently you desire to put in additional tables that appear in this document, you contact the staff of the committee and that will be arranged. We appreciate having you here with us.

Mr. SANDLAND. My name is Clifford Sandland. I am a president and director of the C. F. Braun & Co. For over 50 years we have been engineering and constructing processing plants for the petroleum, petrochemical industries.

On behalf of our company, I would like to thank the committee for the opportunity of meeting with you today. Our particular discussion will concentrate on the historical development of three large-volume chemical products. Our purpose is to demonstrate that continued investigation by engineers usually results in better ways of reaching three objectives—lower investment, lower operating cost, and, finally, lower product cost, almost regardless of the chemical.

A demand for the product of the plant creates a demand for lower cost products. Very few chemicals have failed to respond to the efforts of many engineers vying with each other to produce better plants.

The saline water control process is still in the developmental stage. Right now the cost of the product is relatively high. What is the likelihood that the cost can be reduced? What are the factors that will contribute to reduced costs?

We can answer some of these questions directly and others indirectly by looking at the history of recent developments in three chemicals—ammonia, ethylene, and alkylate. In recent years, all have had an increase in demand. All have responded to the efforts of the engineers.

Let us take a minute to review the factors that contribute to cost reductions. First, perhaps, is the demand for the product. Then there is competition. Competition can be between the organizations selling the product. And it can also be between the firms engineering the process plants. Usually, it is both. Each process also requires equipment—furnaces, compressors, pressure vessels, instruments, and the like.

Competition among the companies producing such apparatus and machinery can also help reduce both capital investment and operating costs.

Now, we will touch upon the four main areas the engineer is best able to influence, all of which affect the cost of the product. These areas are, first, the cost of the plant itself, especially material and equipment such as compressors, furnaces, pressure vessels, heat exchange equipment, piping, instruments, and electrical gear.

Second is the energy requirements of the plant, usually in the form of electricity or fuel.

Third is operating manpower and maintenance.

Fourth is the raw material requirements of the plant such as gas, oil, water, and the like. Many times the raw materials make up the major portion of the manufacturing cost, hence they can be quite important.

The engineer also works to improve process techniques. He will convert batch processes to continuous operation. He will combine separate operations, and apply better controls as they are developed. New techniques developed for one process will be applied to others. The engineer is continuously working on ways to handle higher temperature coupled with higher pressures. And beyond all of these developments, the sizes of the process plants are being pushed up and up.

To demonstrate how the application of these principles by the engineer can influence plant and product costs, let us take a look at the processes which produce the three chemicals mentioned earlier—ammonia, ethylene, and alkylate. There are several processing steps in the processes that produce each of these materials, just as there are several steps in the conversion of saline water to fresh water. We plan to go into some detail as to how the engineer's improvement on individual steps resulted in overall reduction in both capital investment and manufacturing costs.

Senator ANDERSON. Let me interrupt for just a second. There are members of the committee who are not here today and sometimes we have submitted questions at a later date to the witnesses.

I wonder if you would mind, Mr. Sandland, if at a later time we submitted to you some questions for answer because this is a scientific paper. We might want some answers as we go along.

Mr. SANDLAND. Not at all. I would be happy to answer them for you.

Senator ANDERSON. And we might do the same thing with Mr. Bush also.

I want to show in the record that authority is granted to put the questions and answers in at the end of your testimony, if so desired, and also for Mr. Bush because sometimes we cannot get all of these things together at one place.

Mr. SANDLAND. Surely.

Senator ANDERSON. These will not be hostile questions, but purely attempts to find out for the committee.

Mr. SANDLAND. Fine. I will be very happy to answer those questions at a later time.

Senator ANDERSON. Thank you very much.

Mr. SANDLAND. Ammonia is basic to the chemical fertilizer industry. Whether the fertilizer is applied as gaseous ammonia, liquid ammonia, or as ammonium nitrate, ammonium sulfate, urea, or a mixed fertilizer, the starting material is ammonia.

Just as a reference point the old-fashioned fertilizer that is taken out of the barn by the farmer contains roughly 2 percent nitrogen. All we need to produce this important product is nitrogen which we get from the air and hydrogen which we usually get from natural gas and steam.

There are many processing steam steps in the ammonia plant for the purification and the combining of nitrogen and hydrogen. Over the past few years major improvements have been made in the process. For example, advances in metallurgy have resulted in the ability to use higher temperatures in the reformer furnace. This has also permitted operation at higher pressure levels which reduces the horsepower required.

Catalysts required in the process have been improved and are more efficient.

Let me digress for a moment. We have had some discussion this morning on membranes. We have discussed their improvement. There are no catalysts right now in conversion of saline water to fresh water. However, membranes could be equal to the catalyst and we are saying that improvements in catalysts have led to improvements in ammonia. There are improvements in membranes which should help improvements in the saline water conversion program.

Mr. Chairman, the prepared statement contains six charts that show the changes in cost that have occurred in the manufacture of ammonia during the last 10 to 12 years. The largest single item of manufacturing cost is natural gas which is used as a feed stock as well as fuel. Its price has been rising steadily.

Construction labor costs are also increasing. Despite all of this, both the capital investment and operating manpower of ammonia have been markedly reduced. The net result is that the bulk price of ammonia has constantly decreased. We say and estimate that about one-half of the reduction in investment in ammonia plants comes from the increase in the size of the plant. The other half comes from improvements in processing schemes, materials of construction, and equipment design.

The reduction in manufacturing cost of ammonia is due primarily to improvements in processing equipment and automatic controls.

Now, let us take a look at another chemical plan. This produces ethylene that is used as a building block for petrochemicals. This is

one of the largest consumers in the plastics industry. The most familiar plastic made from ethylene is polyethylene. It has many uses, for example, all cardboard milk containers are coated with a thin layer of polyethylene. It is also used in the manufacture of squeeze bottles.

Ethylene, like ammonia, is a fairly simple chemical whose manufacture requires many complicated processing steps. Again, we start with a furnace. This time, the gases to the tubes in the furnace are steam and a hydrocarbon such as ethane, propane, or naphtha. The hydrocarbon breaks down and other compounds are formed, including ethylene. To get the maximum amount of ethylene and the minimum amounts of undesirable compounds and coke, the reaction time must be closely controlled. The gas must be heated to about 1,500° F. and then cooled rapidly to about 1,000° F.

The prepared statement includes four charts which show the changes in cost that have occurred in the manufacture of ethylene in the past 9 years.

Briefly, there have been decreases in operating manpower and manufacturing cost per ton of ethylene produced. This is reflected in the steadily decreasing list price of ethylene. We also have in the prepared statement a comment on alkylate, which is one of the ingredients in high octane gasoline. It has also become in constant demand due to the demand of the high compression engines in the automotive industry which require premium gasoline of an octane rating of around 100.

Alkylate again has responded to the same treatment of the engineer in reducing operating manpower, capital cost, and energy requirements.

In conclusion the combination of demand for the product and competition among the producers and competition among engineering companies has historically resulted in a lower capital investment for the plant and a lower manufacturing cost for the product.

While we selected the three chemicals mentioned as examples, we could cite the same pattern for many, many others. The time-honored method to improve any given process is to break it down into its various elements and study each one for means of improvement. The capital investment is thereby reduced by concentrating on areas of high cost and developing ways and means of lowering them.

Manufacturing costs are lowered by improving operating efficiency and reducing raw material and energy requirements. With the increasing demand for fresh water and the limitations of natural supplies, it appears necessary that we develop processes for upgrading water which would not otherwise be usable.

There is good reason to believe that by using the same engineering ingenuity in attacking the problem that has been used by other industries, we can and will reduce both the capital investment and the manufacturing cost of this fresh water.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you for a very interesting statement.

Just this one question. What is the interest of your company in the desalting program? Do you work in that field?

Mr. SANDLAND. We are now doing work in the field of desalination of water under a contract with the Office of Saline Water. We have just started in this field, barely scratched the surface.

Senator ANDERSON. That is very good and I am happy you are associated with this program. I trust things will come from it. I appreciate your appearance and you may go through this carefully and we may have questions to direct to you later on.

Mr. SANDLAND. Fine. I will be happy to answer them for you. (The prepared statement of Mr. Sandland follows:)

STATEMENT OF CLIFFORD M. SANDLAND, VICE PRESIDENT, C. F. BRAUN & CO.

Mr. Chairman, on behalf of C. F. Braun & Co., I would like to thank the committee for the opportunity of meeting with you today. Our particular discussion will concentrate on the historical development of three large-volume chemical products. Our purpose is to demonstrate that continued investigation by engineers usually results in better ways of reaching three objectives—lower capital investment, lower operating costs, and, finally, lower product cost.

Almost regardless of the chemical product selected for investigation, the history is about the same. A demand for the product of the plant creates a demand for lower cost plants and a lower cost product. Very few chemicals have failed to respond to efforts of many engineers vying with each other to produce better plants.

The saline water conversion process is still in the development stage. Right now the cost of the product is relatively high. What is the likelihood that the cost can be reduced? What are the factors that will contribute to reduced costs?

We can answer some of these questions directly, and others indirectly, by looking at the history of recent developments in three chemicals—ammonia, ethylene, and alkylate. In recent years all have had an increase in demand. All have responded to the efforts of the engineers.

Let's take a minute to review the factors that contribute to cost reductions. First, perhaps, is the demand for the product. Then there is competition. Competition can be between the organizations selling the product. And it can also be between the firms engineering the process plants. Usually it is both. Each process also requires equipment—furnaces, compressors, pressure vessels, instruments, and the like. Competition among the companies producing such apparatus and machinery can also help reduce both capital investment and operating costs.

Now we will touch upon the four main areas the engineer is best able to influence—all of which affect the cost of the product. These areas are, first, the cost of the plant itself, especially material and equipment such as compressors, furnaces, pressure vessels, heat exchange equipment, piping, instruments, and electrical gear. Second is the energy requirement of the plant, usually in the form of electricity or fuel. Third is operating manpower and maintenance. And fourth is the raw material requirements of the plant, such as gas, oil, water, and the like. Many times the raw materials make up the major portion of the manufacturing cost, hence they can be quite important.

The engineer also works to improve process techniques. He will convert batch processes to continuous operation. He will combine separate operations, and apply better controls as they are developed. New techniques developed for one process will be applied to others. The engineer is continuously working on ways to handle higher temperature coupled with higher pressures. And beyond all of these developments, the sizes of the process plants are being pushed up and up.

To demonstrate how the application of these principles by the engineer can influence plant and product costs, let's take a look at the processes that produce the three chemicals mentioned earlier—ammonia, ethylene, and alkylate. There are several processing steps in the processes that produce each of these materials—just as there are several steps in the conversion of saline water to fresh water. We plan to go into some detail as to how the engineer's improvement on individual steps resulted in overall reduction in both capital investment and manufacturing costs.

AMMONIA

Ammonia is basic to the chemical fertilizer industry. Whether the fertilizer is applied as gaseous ammonia, liquid ammonia, or as ammonium nitrate, ammonium sulfate, urea, or a mixed fertilizer, the starting material is ammonia.

In both ammonia and other fertilizers, we want the nitrogen in an easily available and controllable form. Ammonia gives the highest concentration of

nitrogen available—80 percent. By comparison, ammonium sulfate is 20 percent nitrogen; ammonium nitrate, 33 percent; and urea, 46 percent. Just as a reference point, the old-fashioned fertilizer that comes out of the farmer's barn contains 2 percent nitrogen.

The chemical composition of ammonia is NH_3 —one atom of nitrogen combined with three atoms of hydrogen. So all we need to produce this important product is nitrogen, which we get from the air, and hydrogen, which we usually get from natural gas and steam. The major part of the ammonia plant itself is for the purification of nitrogen and hydrogen. Let's briefly discuss some of the reactions and see what happens.

Reformer furnace.—Hanging in this furnace are stainless tubes about 4 inches in diameter containing a catalyst. The tubes are heated to about 1,600° F., and a mixture of natural gas and steam is run through them. The product is the hydrogen we need plus carbon dioxide, carbon monoxide, and a small amount of unreacted natural gas.

Next, air is added to these gases and the mixture burns in the presence of a catalyst. Oxygen from the air provides the energy. The resulting products are more hydrogen, nitrogen, carbon monoxide, carbon dioxide, and steam. The remaining carbon monoxide is converted to carbon dioxide, and removed with the steam. We now have essentially pure hydrogen and pure nitrogen. But they aren't in combined form. The mixture of nitrogen and hydrogen is compressed to a pressure in the range of 2,000 to 6,000 pounds per square inch. This high-pressure gas is sent through still another catalyst where a portion of the nitrogen and hydrogen combine to give ammonia. The uncombined elemental gases are mixed with the fresh gases and recycled back through the catalyst. In this way, eventually, quite complete combining of the nitrogen and hydrogen to ammonia takes place.

Over the past few years, major improvements have been made in all the processing steps in ammonia manufacture. For example, we are able to use higher temperatures in the reformer furnace. This is the result of advances in metallurgy so the tubes are capable of withstanding such temperatures. Not only can we go to the higher temperatures, but we can also operate at the required higher pressures. This, in turn, permits smaller vessels, smaller piping, and less horsepower for compression.

We briefly outlined above the number of reactions that require catalysts. Many improvements also have been made in these catalysts so that the reactions can be carried out at temperature and pressure levels that reduce energy requirements and consequently costs. The catalysts are also more efficient. This results in higher conversion rates during the first pass through the catalyst, and reduces the amount of unconverted nitrogen and hydrogen that must be recycled. Here again, we realize the benefits in lower capital investment and operating costs.

Increasing the size of the plant usually means a reduction in unit costs. In ammonia plants, larger equipment is now being used rather than multiple items connected in parallel. Fewer items saves on the cost of the equipment itself, piping, foundations, plot space, maintenance, and usually saves on operating manpower.

Increased plant size also has permitted the use of centrifugal compressors in place of reciprocating. The centrifugal compressors are less expensive, require less space and smaller foundations, and in general, require less maintenance.

Now let's see what changes in costs have occurred in the last 10 to 12 years. Figure 1 shows how the capital cost per ton of ammonia has decreased since 1953. This chart shows relative costs with 1953 set at an index of 100. This reduction in cost per ton of ammonia has been effected despite constantly rising construction costs. Figure 2 shows how construction costs have increased since 1953.

Figure 3 shows how operating manpower per ton of ammonia has reduced. This reduction has taken place in spite of constantly rising labor costs. The operating labor index shows in figure 4.

The largest single item of cost is natural gas. This is used as a feed stock as well as a fuel. Figure 5 shows the increase in the cost of natural gas.

And what has happened to the price of ammonia? Despite increases in costs of construction, labor, and feed stock, the bulk price of anhydrous ammonia has constantly decreased (see fig. 6).

We estimate that about one-half of the reduction in investment in ammonia plants comes from the increase in size of the plants. The other one-half comes from improvements in processing schemes, materials of construction, and equipment design.

The reduction in manufacturing cost of ammonia is due primarily to improvements in the processing schemes, equipment design, and automatic controls.



Ammonia Plant

ETHYLENE

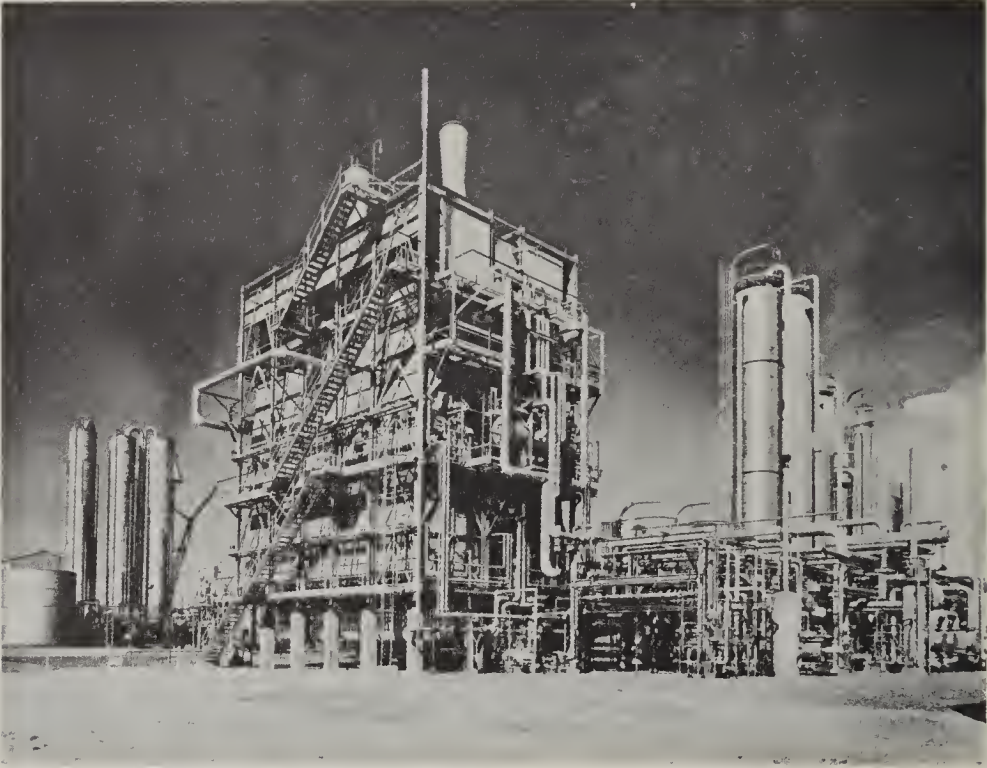
So much for the story on ammonia. Now let's look at another type of chemical plant. This one produces ethylene that is widely used as a building block for petrochemicals. One of the largest consumers is the plastics industry. The most familiar plastic made from ethylene is polyethylene. It has many uses. For example, all cardboard milk containers are coated with a thin layer of polyethylene. It is also used in the manufacture of squeeze bottles.

Ethylene, like ammonia, is a fairly simple chemical whose manufacture requires many complicated processing steps. Again we start with a furnace. This time, the gases to the tubes in the furnace are steam and a hydrocarbon such as ethane, propane or naphtha. The hydrocarbon breaks down and other compounds are formed including ethylene. To get the maximum amount of ethylene and the minimum amounts of undesirable compounds and coke, the reaction time must be closely controlled. The gas must be heated to about 1,500° F. and then cooled rapidly to about 1,000° F.

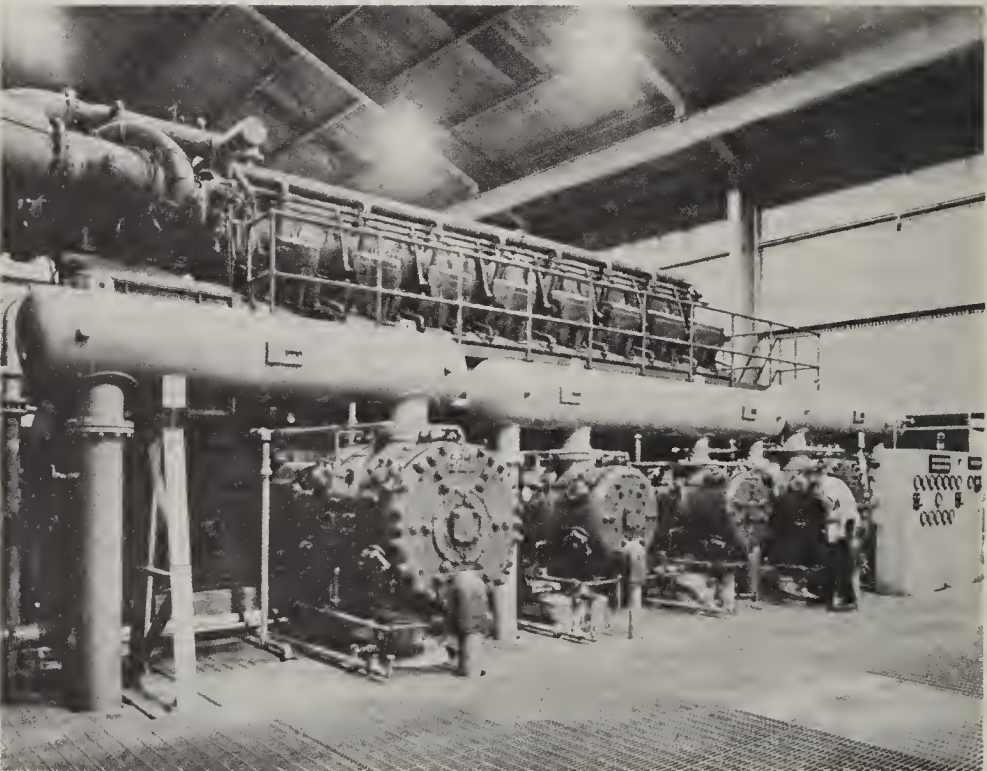
Next are the several steps for removing the undesirable compounds. First the gas is washed. Then it is compressed, washed with caustic, and dried. Final separation is by fractionation. In this process, the various components are separated by taking advantage of their different boiling points. The unusual feature in ethylene separation is that the temperatures for fractionation vary from minus 225° F. to plus 400° F.

The components that we labeled undesirable are undesirable only in that the main product is ethylene. However, an ethylene plant also produces a mixture of methane and hydrogen, ethane, propylene, and butadiene—all useful chemicals themselves.

In the past several years, considerable research has gone into the ethylene process. Most of this effort has been in the furnace where ethylene is produced. As the result of work on quench rates, reaction times and the other variables in cracking, the yield of ethylene for a given feed gas has been increased. A higher yield reduces the feed quantity for a given amount of ethylene, and it also permits a reduction in the size of the separation steps following the reaction.

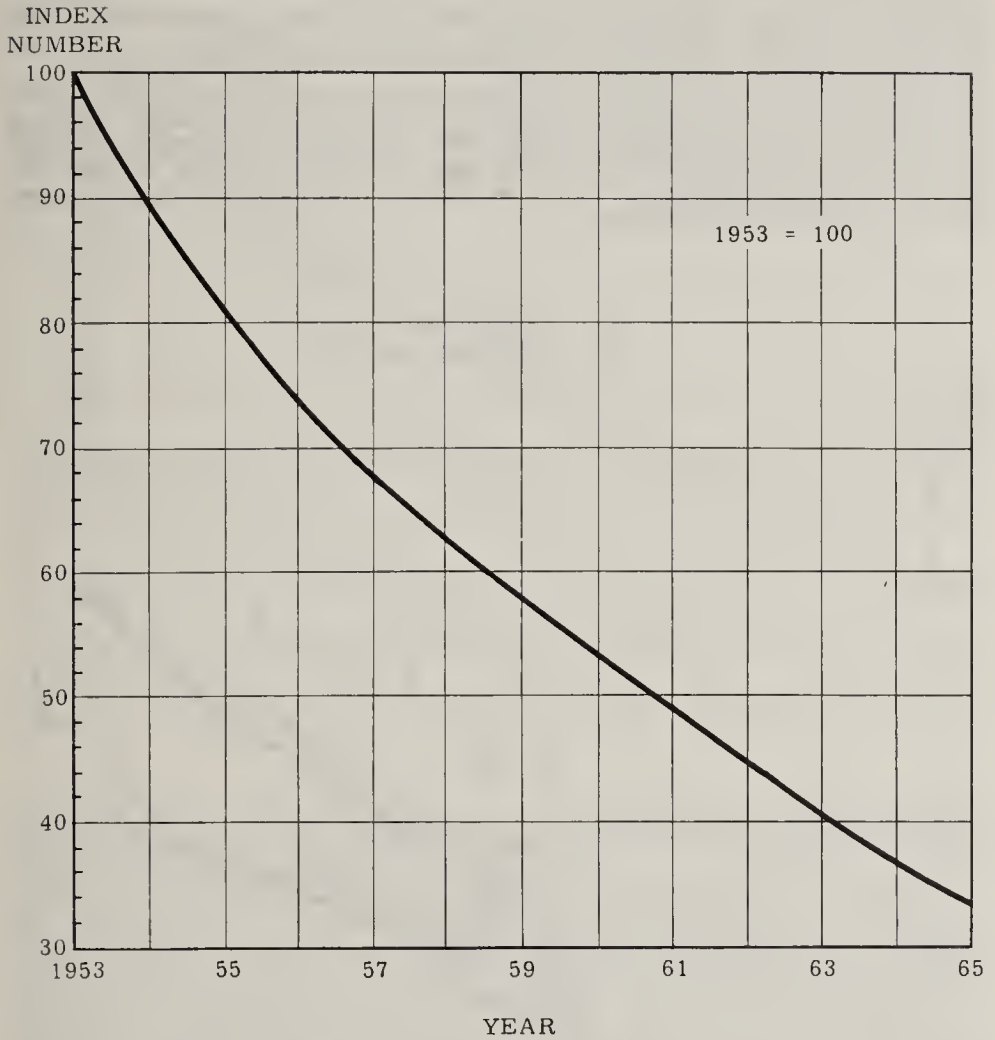


Ammonia Plant - Reformer Furnace



Ammonia Plant - Reciprocating Compressor

FIGURE 1
CAPITAL COST PER TON OF AMMONIA



Higher reaction temperatures have improved the process. Better low-temperature fractionation has also helped. Larger plant sizes, as with ammonia, has helped reduce plant costs. It was not too long ago when a plant capable of producing 200 million pounds a year of ethylene was considered to be a large plant. Now, 500 million pounds a year is considered commonplace. And companies are planning installations with a capacity of 1 billion pounds a year. Again, these increases in plant size have permitted the use of centrifugal compressors instead of reciprocating. And there have been improvements in the sequencing of the separation steps.

Very recently the temperature in the cracking furnace has been raised. For certain feed stocks, the yield of ethylene increased significantly. This has had a marked effect on the costs to produce ethylene and on its price.

Figure 7 shows the changes in capital cost per ton of ethylene since 1956. Figure 8 shows how operating manpower has decreased since 1956. Figure 9 gives a measure of the change in efficiency. The energy required is the sum of electrical energy plus energy in fuel used in heating. Figure 10 gives the list price index for ethylene. Here you can see the effect of process changes made only within the last 2 years.

FIGURE 2
CONSTRUCTION COSTS

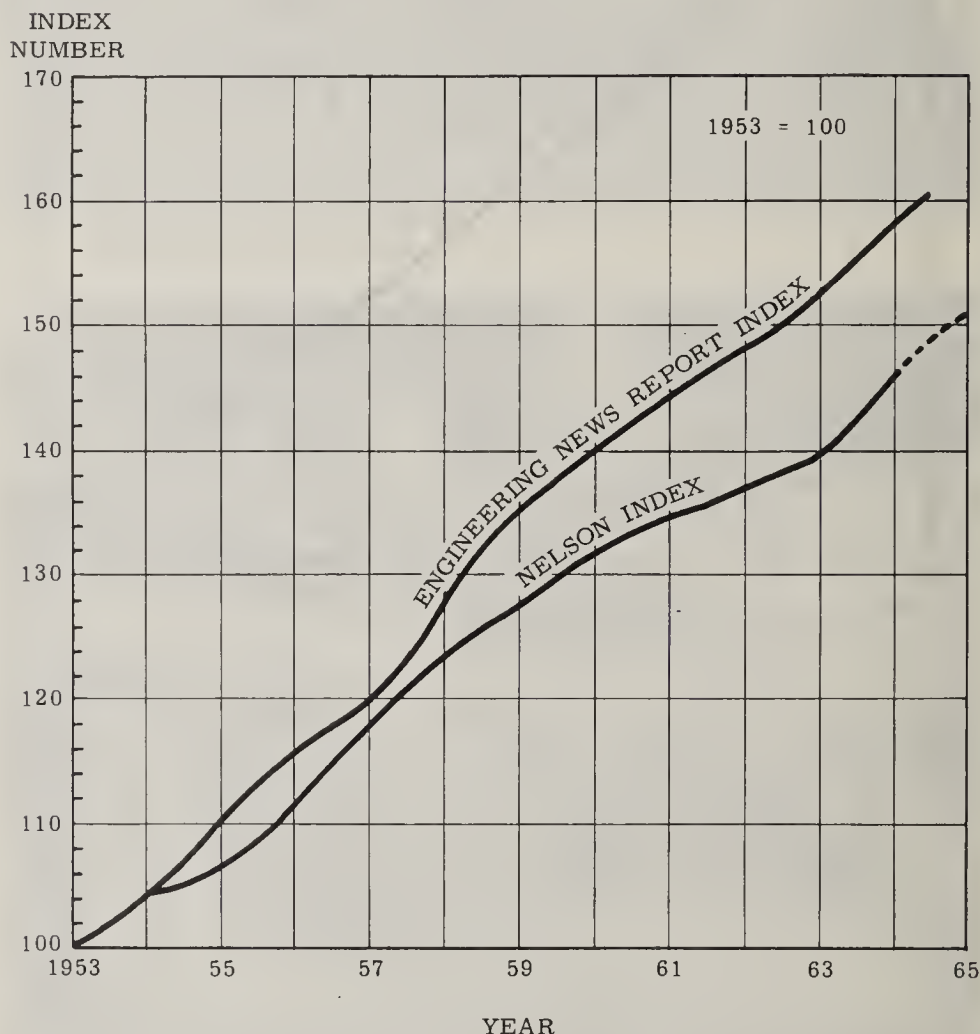
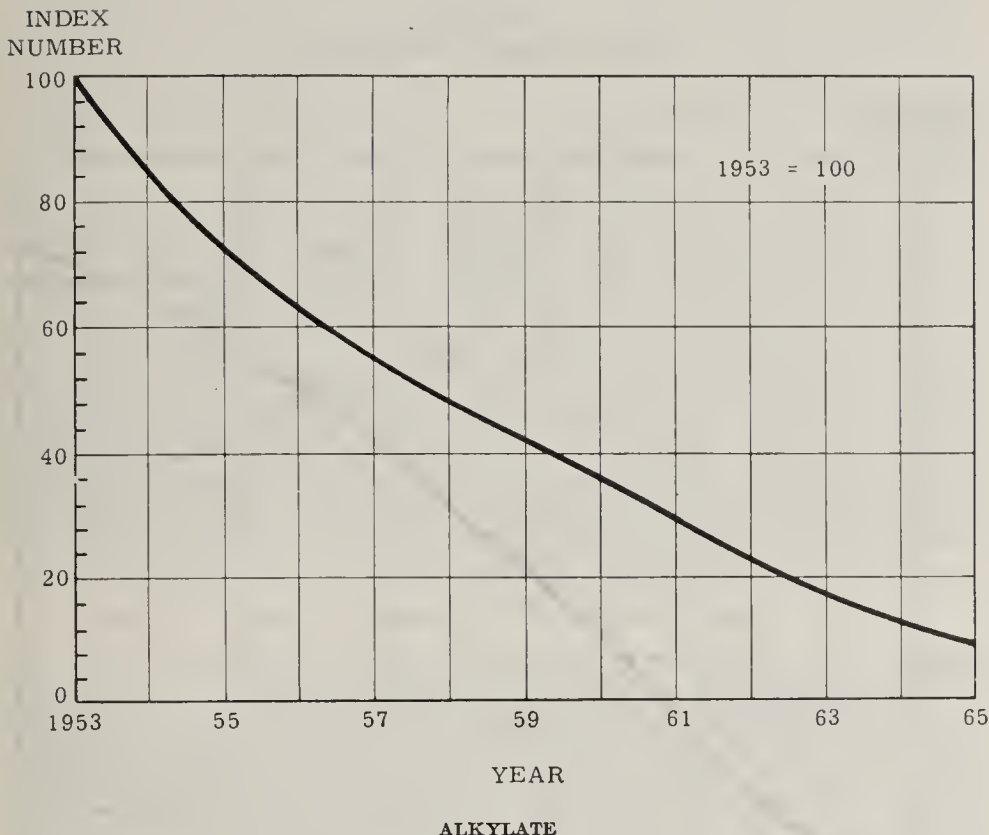


FIGURE 3
OPERATING MANPOWER PER TON OF AMMONIA



Alkylate is one of the ingredients in high octane gasoline. During World War II, many alkylation plants were built for the aviation gasoline program. After the war, the demand for alkylate fell off.

Then in the fifties, automobile manufacturers began taking advantage of the fuel economy of high-compression engines. These engines require high octane gasoline. Alkylate is one of the components that helped raise the octane rating to the present value of around 100 for premium gasoline. As a result, many plants were built to meet the increasing demand of the automobile.

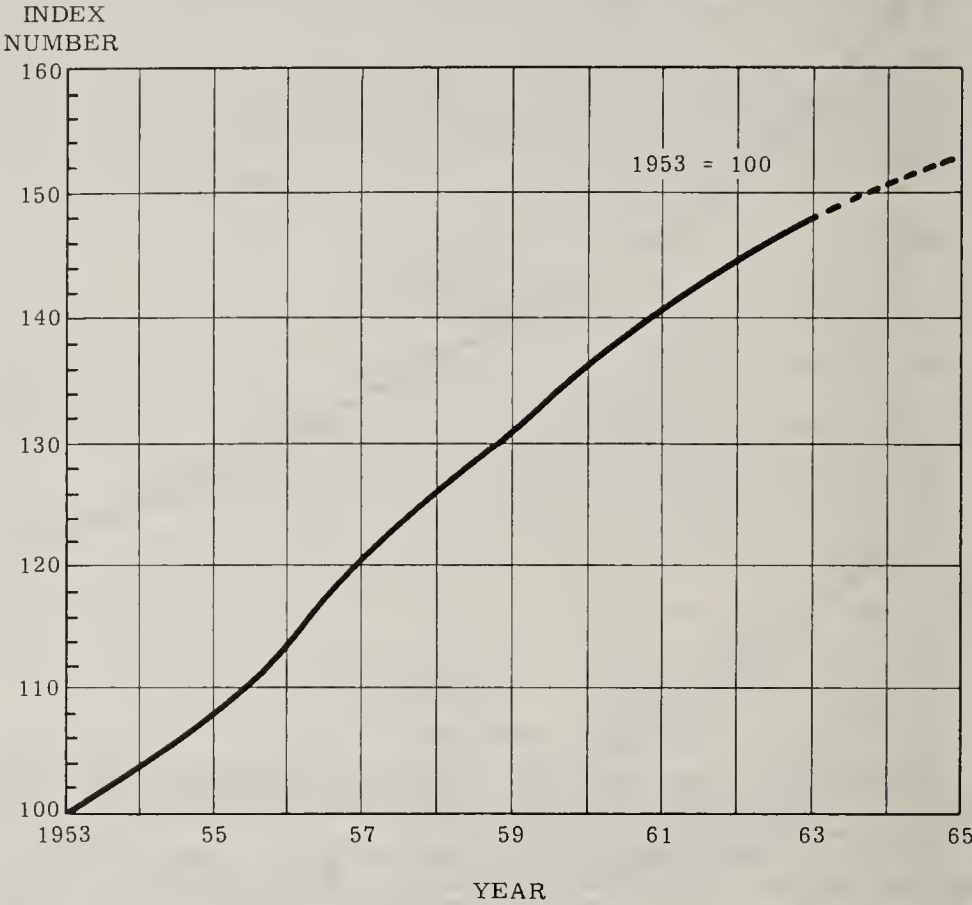
Alkylate is not a single chemical, but is a mixture of hydrocarbons. To make alkylate, isobutane is reacted with olefins in the presence of a catalyst. Isobutane and olefins are products from a catalytic cracker whose main product is gasoline. Some of the hydrocarbons have higher octane numbers than others. Alkylate is one of them.

Reaction conditions must be carefully controlled so as to produce a maximum amount of the higher octane components. The alkylate is separated from the unreacted materials in a series of steps. Once separated, it can be added to gasoline without further processing.

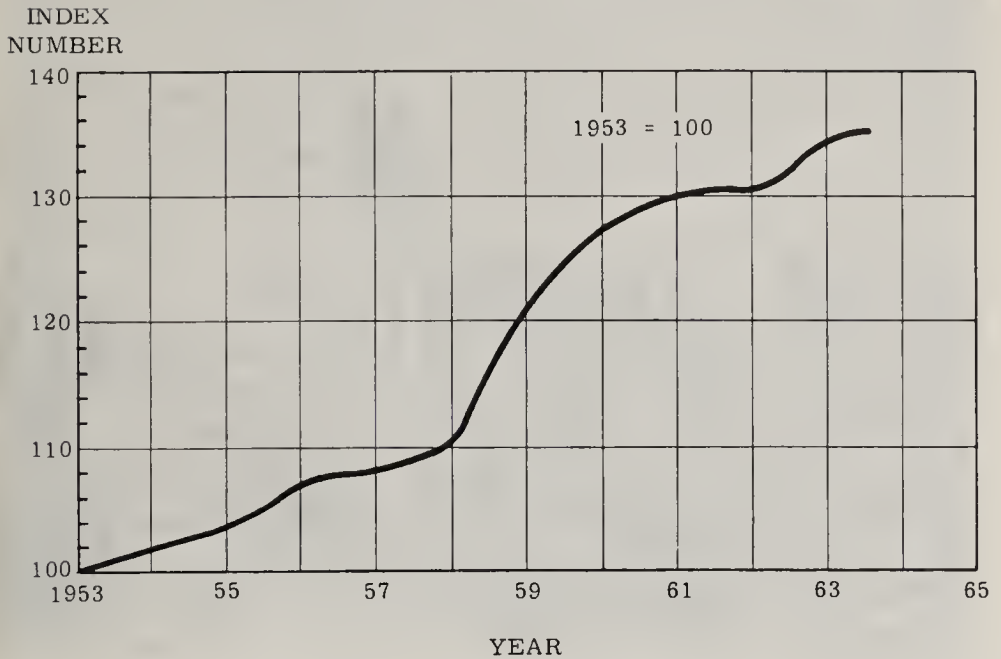
In the past few years, the design of reactors has been greatly simplified. The number of separation steps following reaction has been reduced by combining services. These changes reduced both capital costs and energy costs.

Figure 11 shows the change in capital cost since 1956. Figure 12 shows the decrease in operating manpower that has occurred. And figure 13 shows the reduction in energy used since 1956. Since alkylate is seldom sold as such, list prices are not available for comparison. But there is no doubt that this chemical material has followed the same pattern as ammonia and ethylene.

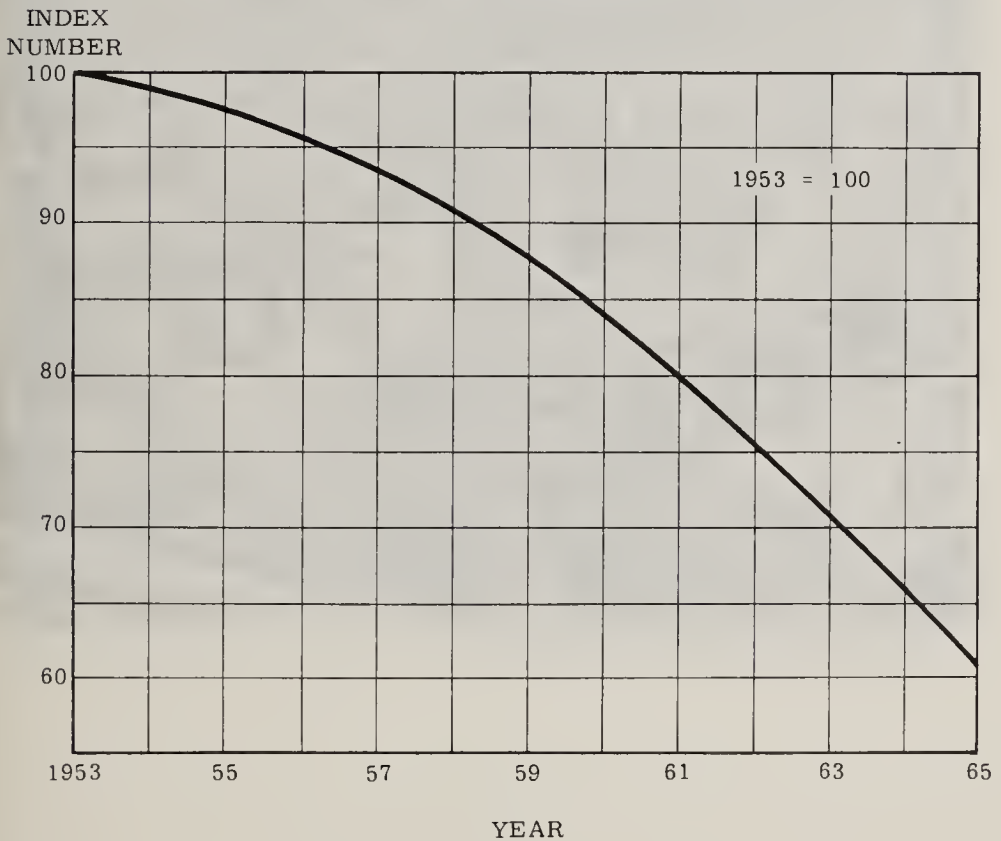
FIGURE 4
OPERATING LABOR COSTS

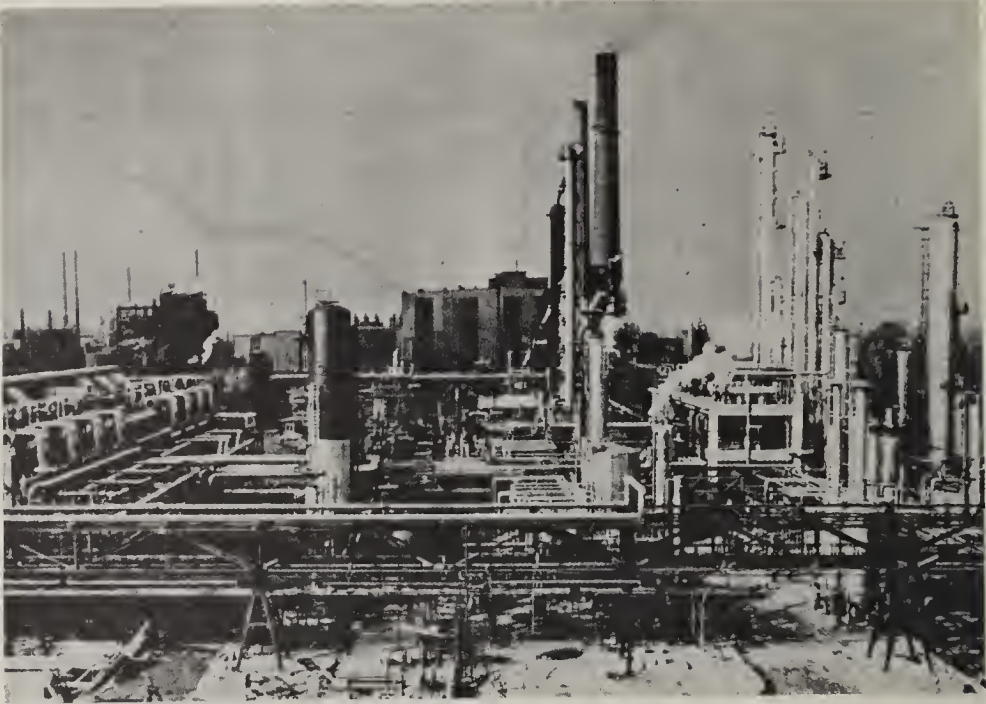


SOURCE Statistical Abstracts of the United States
Chemical Production Workers, Average Hourly Earnings

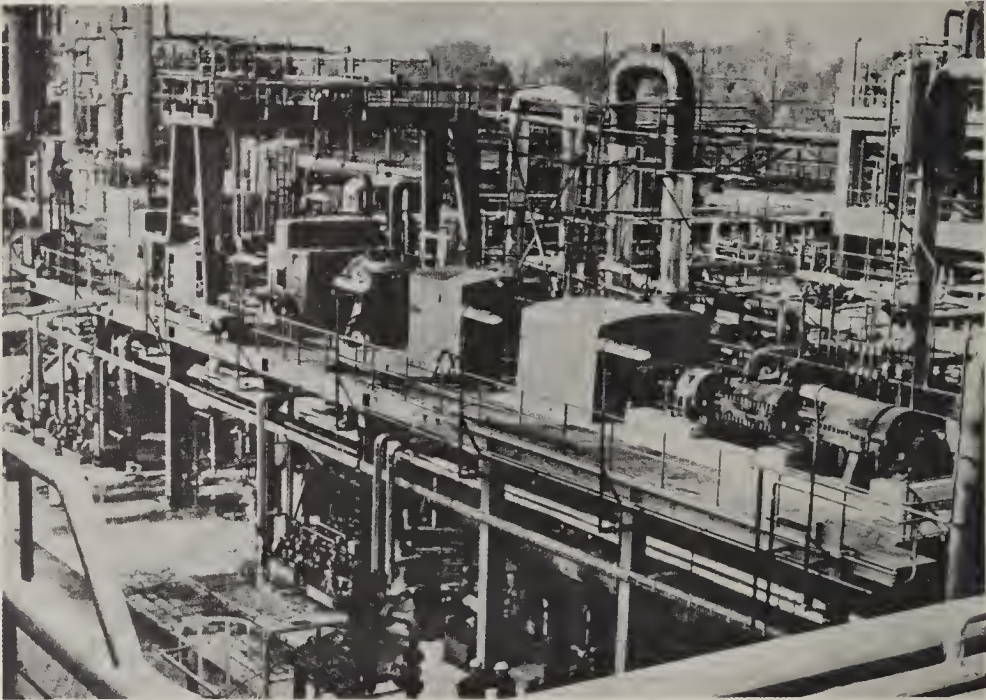
FIGURE 5
NATURAL GAS COST

SOURCE Statistical Abstracts of the United States

FIGURE 6
BULK PRICE OF ANHYDROUS AMMONIA
WESTERN AREA



Ethylene Plant - General View



Ethylene Plant - Centrifugal Compressors

FIGURE 7
CAPITAL COST PER TON OF ETHYLENE

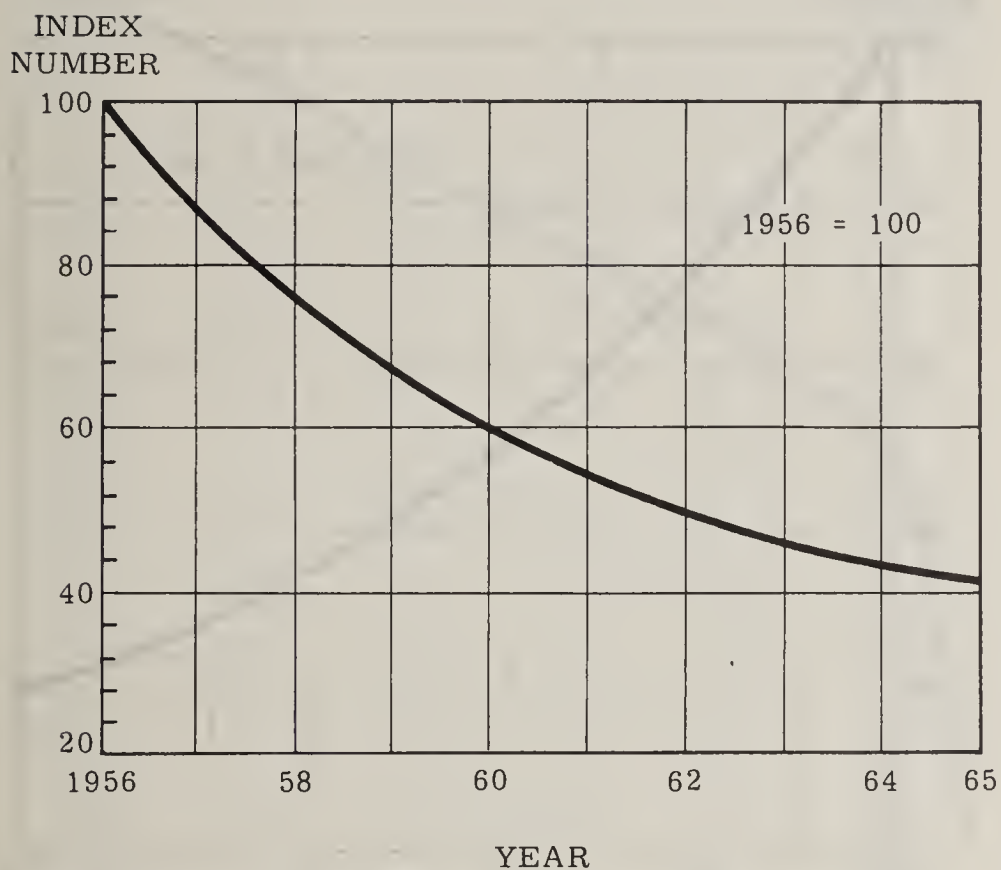


FIGURE 8
OPERATING MANPOWER PER TON OF ETHYLENE

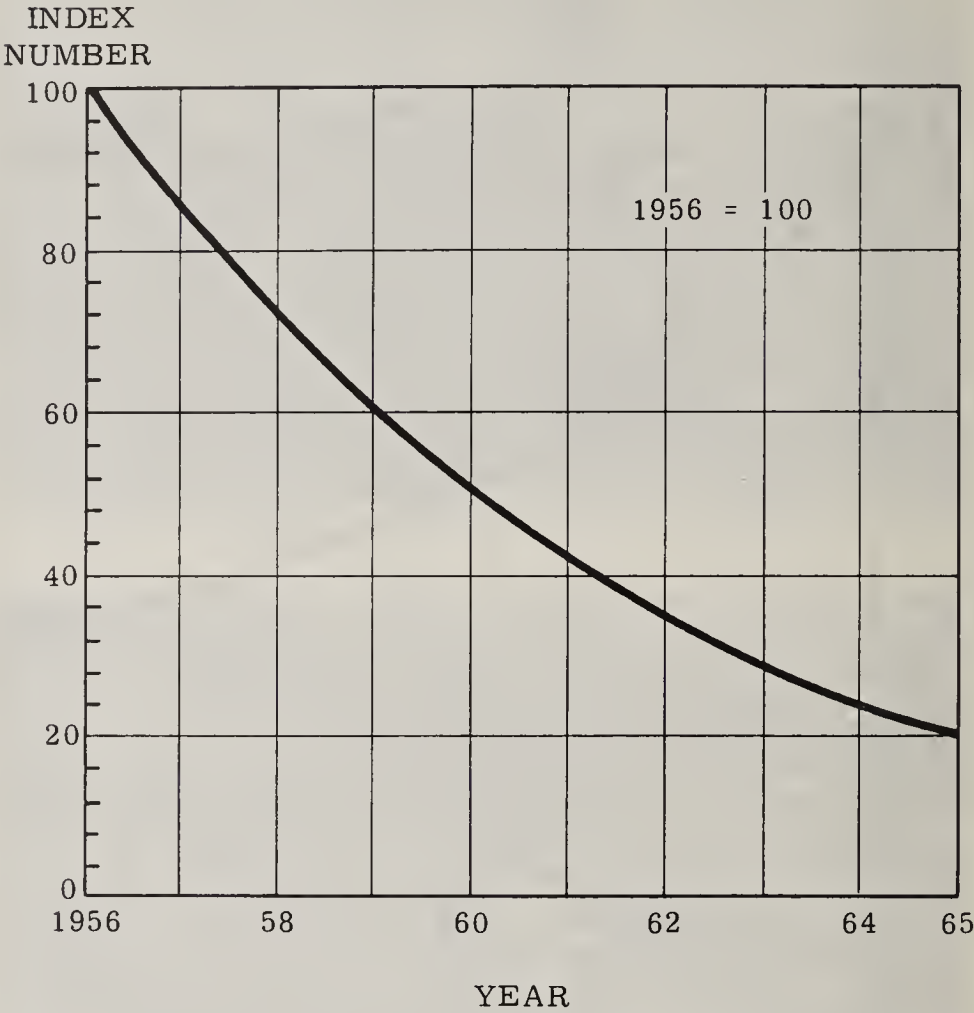


FIGURE 9
ENERGY REQUIRED PER TON OF ETHYLENE

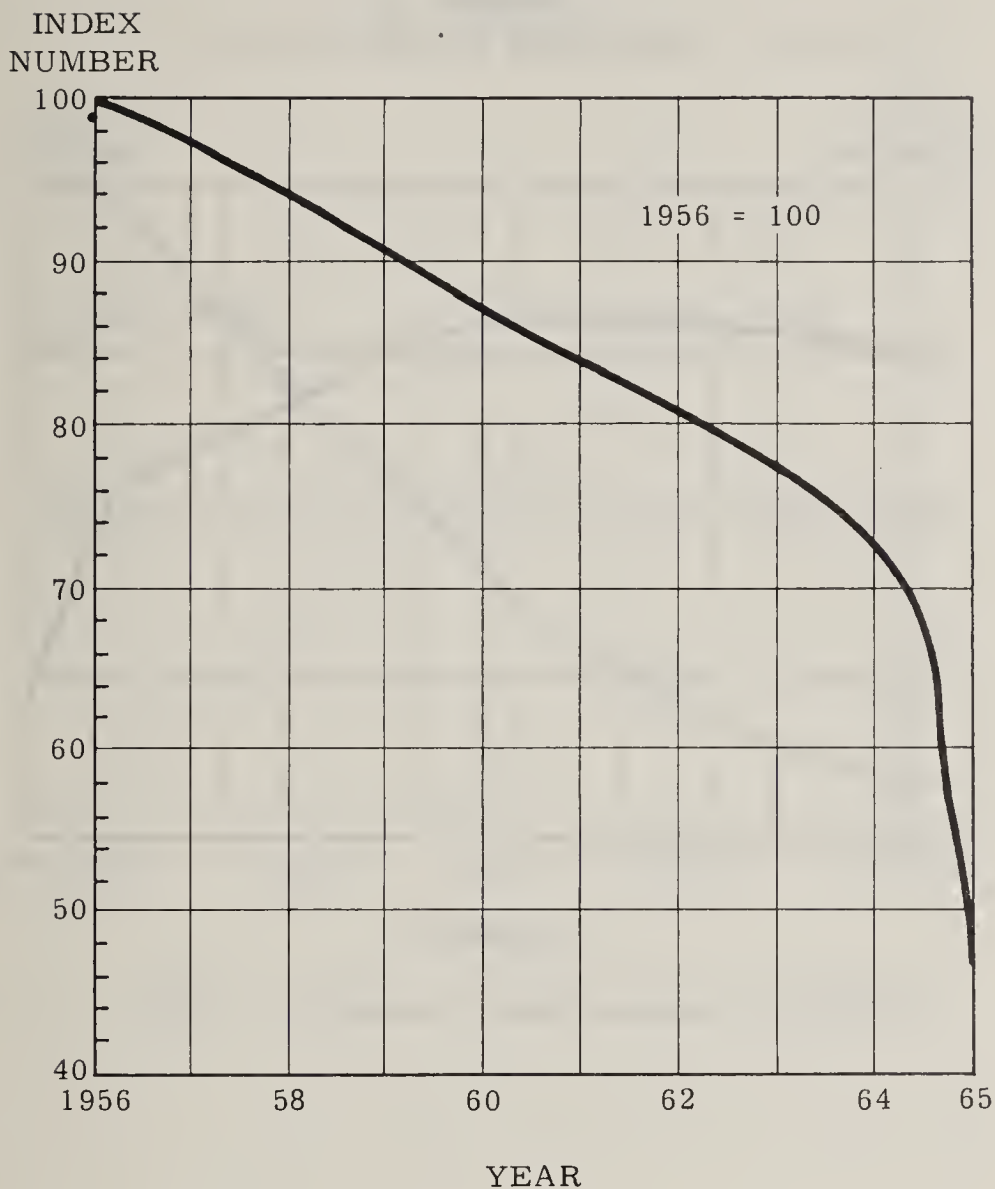
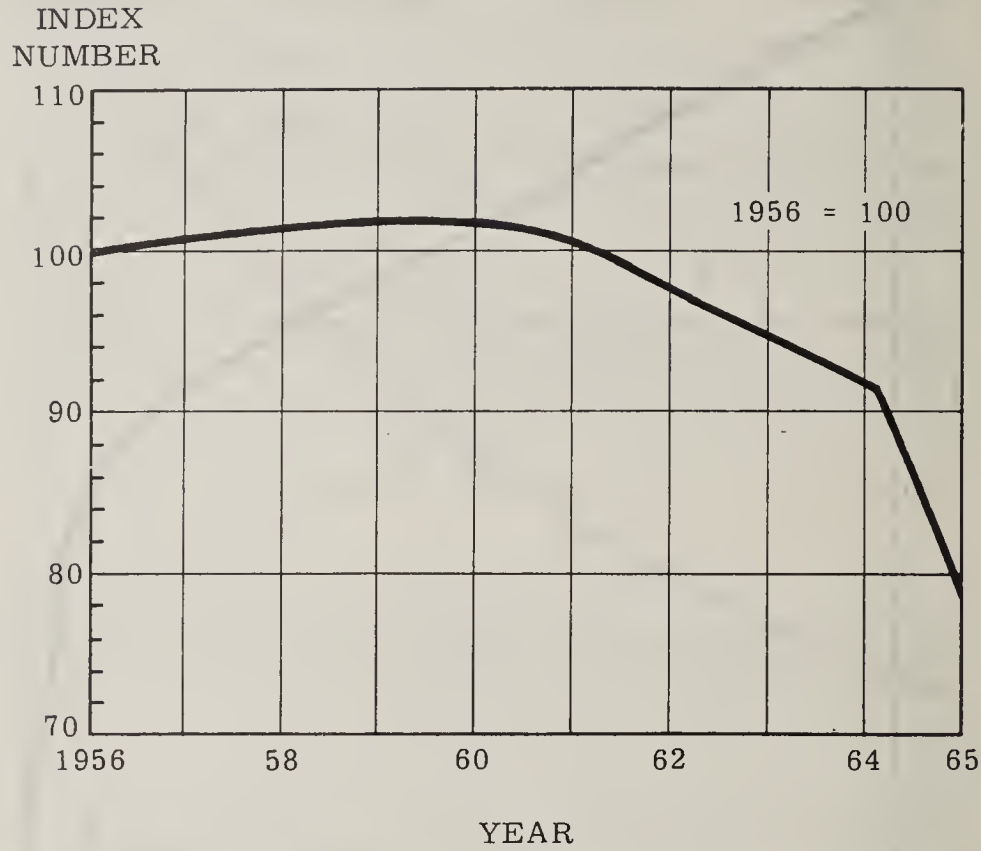


FIGURE 10
LIST PRICE OF ETHYLENE



SOURCE: Chemical Week, January 16, 1965

FIGURE 11
CAPITAL COST PER BARREL OF ALKYLATE

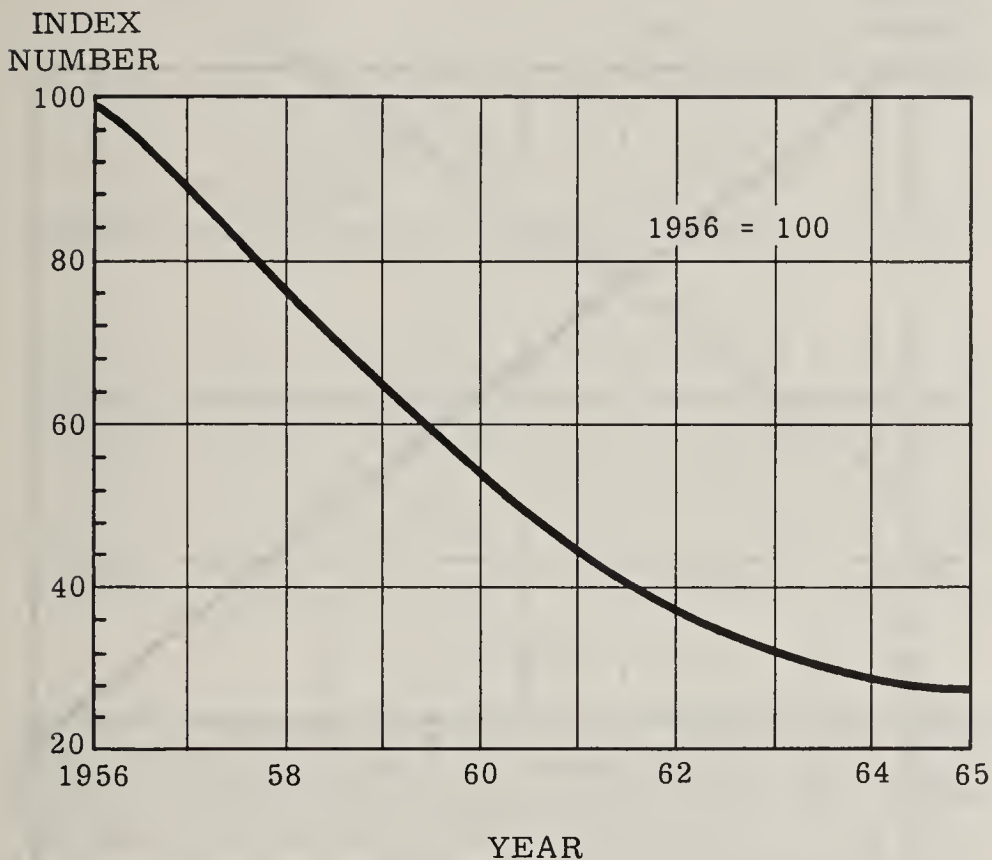


FIGURE 12
OPERATING MANPOWER PER BARREL OF ALKYLATE

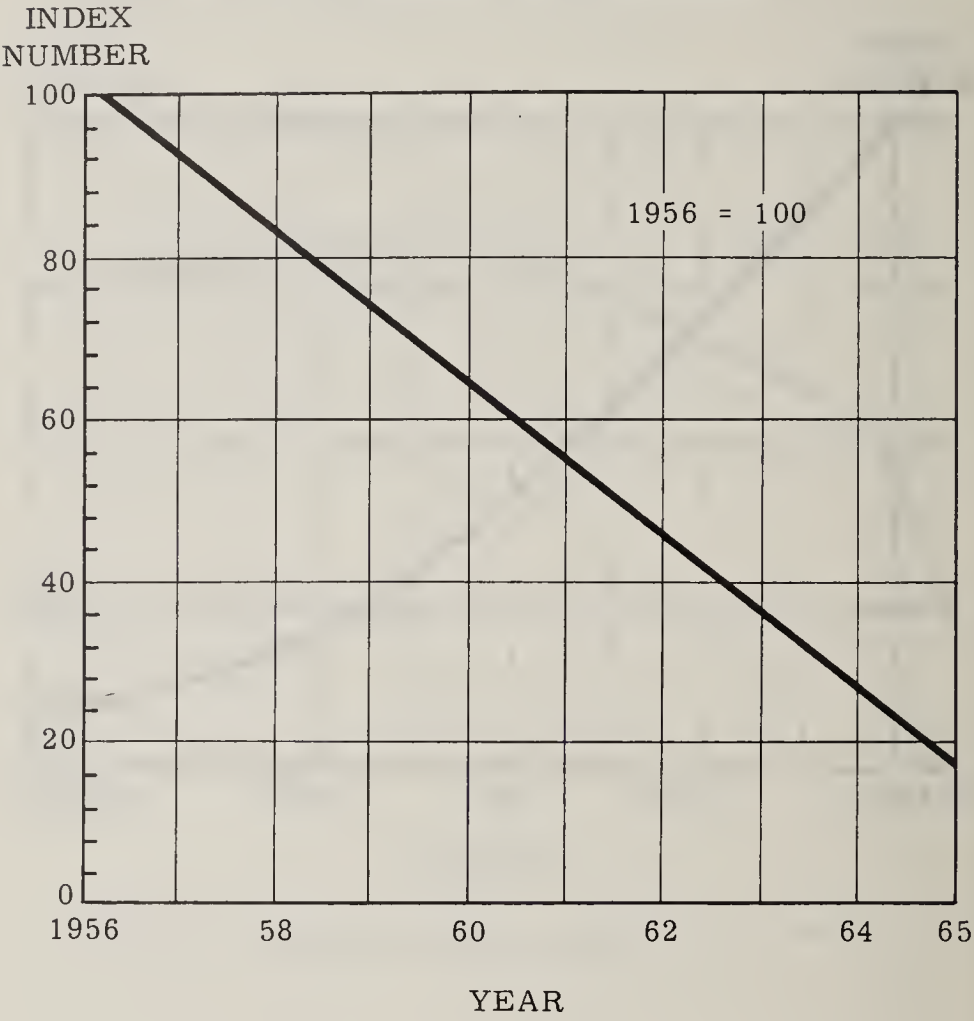
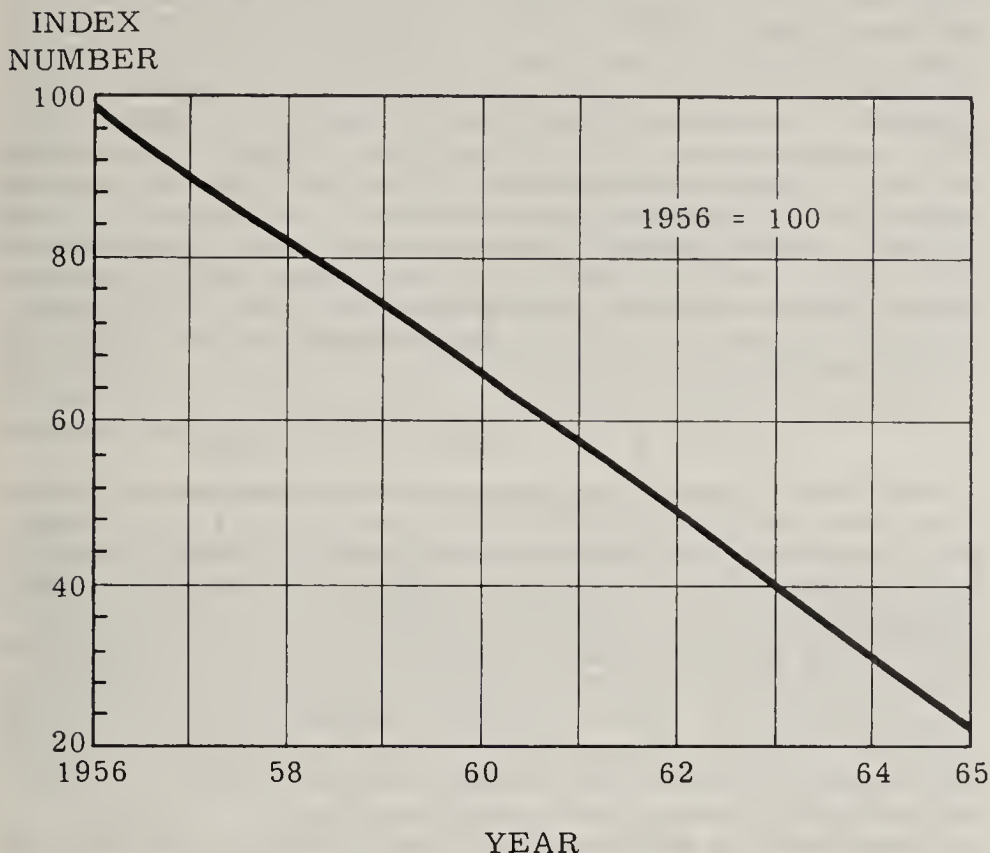


FIGURE 13
ENERGY REQUIRED PER BARREL OF ALKYLATE



Conclusion.—In conclusion, the combination of demand for the product, competition among the producers, and competition among engineering companies has historically resulted in a lower capital investment for the plant and a lower manufacturing cost for the product. While we selected the above three chemicals as examples, we can cite the same pattern for many, many others.

The time-honored method to improve any given process is to break it down into its various elements and study each one for means of improvement. The capital investment is reduced by concentrating on areas of high cost, and developing ways and means of lowering them. Manufacturing costs are lowered by improving operating efficiency, and reducing raw material and energy requirements.

With the increasing demand for fresh water, and the limitation of natural supplies, it appears necessary that we develop processes for upgrading water which would not otherwise be usable. There is good reason to believe that by using the same engineering ingenuity in attacking the problem that has been used by other industries, we can and will reduce both the capital investment and the manufacturing cost of this fresh water.

Mr. Chairman, I thank you.

Senator ANDERSON. Next, we will hear from Mr. Alan M. Nedry.

STATEMENT OF ALAN M. NEDRY, SOUTHERN CALIFORNIA EDISON CO.

Mr. NEDRY. My name is Alan M. Nedry. I am special counsel for Southern California Edison Co., with offices in Washington, D.C., and Los Angeles, Calif.

The Southern California Edison Co. is a California corporation engaged as a public utility in the supply of electricity in the central

and southern portions of the State of California and the western portion of the State of Nevada. The company owns and operates an interconnected steam and hydroelectric generating system located in central and southern California, consisting of 36 hydroelectric stations with a total effective operating capacity of approximately 839,000 kilowatts and 12 steam electric generating stations having a total operating effective capacity of approximately 5,307,000 kilowatts. In addition, under contract with the United States, Edison Co. has available for its use approximately 316,000 kilowatts of effective operating capacity at the Hoover Dam powerplant on the Colorado River, certain of the units of which it operates as an agent of the United States. The company also owns a small steam electric generating plant in the State of Arizona which is operated by another utility. The population of the territory served by the company is estimated to be approximately 6,500,000 persons.

SALINE WATER CONVERSION ACTIVITIES

Since 1959 the company has been very interested in the desalination of sea water and has operated a small conversion plant so as to obtain actual experience with desalination equipment of the multiple-stage flash evaporator type. This unit was originally installed at our Mandalay generating station near Oxnard, Calif. It has a nominal capacity of 100,000 gallons per day. This unit was built to investigate the feasibility of combining power production and sea water conversion in a single facility. The purpose in investigating this dual-purpose concept was based on the reduction in water production costs which can be achieved by the use of low-pressure steam for sea water evaporation after partial expansion through the turbine.

Operation of this experimental conversion plant at Mandalay over a 4-year period demonstrated the ability of this type of equipment to perform satisfactorily in combination with a steam electric generating unit and provided valuable information on evaporator operating characteristics and on the serviceability of various materials of construction. Additionally, problems with scale formation and resultant loss of efficiency were investigated during this period and a practical method of scale control developed which permits operation at 250° F. with a 40-percent increase in water production rate and a reduction in product water cost of approximately 20 percent. The water produced by this plant contains less than 20 parts per million of dissolved solids, well below the 500 parts per million design objective established for the Office of Saline Water demonstration plants.

Following this extensive period of testing, a small 750-kilowatt gas turbine-driven generator was installed at the Mandalay station and the conversion plant operated with exhaust heat from the gas turbine rather than with steam extracted from the 220,000-kilowatt turbine-generator. This major modification was made to determine the feasibility of this type of dual-purpose plant for application in remote, water-deficient areas which, because of relatively small power and water demand, cannot economically be served by a considerably more efficient steam electric generating unit supplying extraction steam to the water conversion plant.

The company has been specifically interested in this type application because of its responsibility to supply water as well as power for Catalina Island, where abnormally low rainfall over the past several years has threatened to create a water shortage. After testing the modified plant at Mandalay for a period of some 8 months, it became apparent that the threatened water shortage on the island would probably develop during this coming summer when the population of the island is temporarily tripled due to the influx of summer residents and tourists. As a result, it was decided to relocate the conversion plant and gas turbine-generator to Catalina as rapidly as possible. This relocation was completed early last month and the unit is now producing water at the new location.

In addition to the considerable amount of experience and information which has been obtained through actual operation of conversion plant equipment, Edison has carried out a number of engineering studies to determine the economic feasibility of both intermediate and large-size conversion plants.

LARGE-SCALE DUAL-PURPOSE PLANT STUDIES

One of these studies was particularly significant since a conceptual dual-purpose plant design with a production capability of 1,500 megawatts of electrical energy and 150 million gallons of fresh water per day was developed in some detail, and the effects of various combinations of financial, operational, and functional plant arrangements evaluated. This study considered both nuclear and oil-fired steam electric generating plants and considered ownership of the water conversion plant by those agencies responsible for water supply and ownership of the power production portion of the plant by those agencies responsible for power supply in the area. The plant design developed by this study consists of two generating units, each producing 750 megawatts net to the electrical system and three 38-stage flash evaporators of 50 million gallons per day capacity each, receiving exhaust steam from one back-pressure turbine common to both main generating units which can operate with either unit out of service if necessary.

The results of this study indicate that a nuclear-fueled, dual-purpose plant having the specified production capabilities can be expected to produce water at a cost of less than 35 cents per thousand gallons while generating electrical energy at a cost of approximately 5 mills per kilowatt-hour. Since these production costs appear to be economically competitive with those which can be anticipated for future water importation projects beyond the California Feather River project, Edison believes that the possible use of large, dual-purpose nuclear plants located close to the points of water use should receive detailed study and evaluation.

With this in mind, early in the discussions between the Metropolitan Water District—MWD—the Department of the Interior, and the Atomic Energy Commission, Edison and other power-generating agencies in southern California offered to cooperate and assist in any joint study. Power is a part of desalination and those entities in the power-generating business in southern California felt they could best provide the needed information for such study and evaluation.

This committee is aware that, under the terms of this contract, which was announced in August of 1964, the MWD assumed overall responsibility for the conduct of an engineering and economic feasibility study of a combination power and desalting plant using a nuclear energy source. An advisory power task force comprised of representatives of the city of Los Angeles Department of Water and Power, San Diego Gas & Electric Co., and the Southern California Edison Co., was appointed to work with MWD to prepare a realistic basis for marketing electric power produced at the dual-purpose plant.

After a series of meetings with MWD and its subcontractor, the Bechtel Corp., the three southern California utilities, on April 8, 1965, formally transmitted to MWD a set of principles for joint participation in the construction, ownership, and operation of the dual-purpose power desalination plant under study.

The basic principle involved is that both water and power should bear their fair share of the total plant costs. Power from the dual-purpose plant would cost no more than that which would be produced at a similar single-purpose plant at the same site. Water production would bear the cost of the desalination facilities plus only the incremental cost of additional power facilities needed to produce the additional quantities of steam and power required for desalination operation.

The proposal suggested a plant consisting of two large commercial-type nuclear power generating units, a single, smaller back-pressure steam turbine-generator, and a multiple-stage flash evaporator desalination plant capable of producing 150 million gallons of fresh water per day. The net electrical capacity of the plant could be on the order of 1,500 megawatts. Each main nuclear steam supply system would be sized to produce the full-load steam requirement of its associated main turbine-generator plus one-half of the steam required to operate the back-pressure turbine-generator and the desalination plant at full capacity. The back-pressure turbine would furnish desalination plant auxiliary power, power for pumping product water from the site to a point of connection with MWD's distribution system, and supplemental pumping power for MWD's Colorado River aqueduct. The utilities would utilize all power from the main generating units and would also absorb any surplus power from the back-pressure unit. The City of Los Angeles Department of Water and Power, and possibly three other smaller municipalities, would own one of the main power units, San Diego Gas & Electric Co. and the Southern California Edison Co. would jointly own the other main power unit, and the metropolitan Water District would own the back-pressure turbine-generator and the desalination facilities. The ownership of common facilities would be assigned to the parties in such a way that the total capital investment by the power entities would be in proportion to their capacity entitlements and would not exceed equivalent single-purpose plant costs.

The proposed arrangement offers MWD the economy of scale in securing steam from a nuclear heat source and provides the waterplant with greater reliability and flexibility of operation than could otherwise be obtained from a single steam turbine-generator plant. Preliminary estimates indicate that fresh water could be produced at the plant at a cost of less than 30 cents per 1,000 gallons with power production at a cost of less than 5 mills per kilowatt-hour.

We should also like to emphasize that the two nuclear power generating units included in the proposed arrangement would be of a commercially proven type and that Edison and San Diego would contribute to this project the considerable experience being developed with the large power reactor currently being installed at their San Onofre nuclear generating station near San Clemente.

RESOURCE PLANNING PROBLEM

One extremely important consideration sometimes not given proper weight, because the emphasis is put on desalting, is the power features and resources planning aspect. It takes approximately 5 years to design, engineer, and construct a large electric generating station and utilities must commit themselves that far in advance to the addition of new generating resources to meet their growing customer demands. In order for power from any dual-purpose plant to have value for an electric utility, it must be planned with sufficient notice to provide for its orderly integration into the utility's planned schedule of resources additions.

CONCLUSION

We appreciate the opportunity to present these developments to the committee and reaffirm our deep interest in the urgent problems of saline water conversion. We offer our continuing cooperation with this committee and would be pleased to keep you informed on any further developments.

Senator ANDERSON. We will now hear from Mr. William L. Gore, senior vice president, Aerojet-General Corp.

STATEMENT OF WILLIAM L. GORE, SENIOR VICE PRESIDENT, AEROJET-GENERAL CORP.; ACCOMPANIED BY DR. BERTRAM KEILIN, DEPARTMENT MANAGER, WATER RESOURCES, AEROJET-GENERAL CORP.

Mr. GORE. I am William Gore, of Aerojet-General Corp., and this is Dr. Keilin, who is the manager of our water resources, Aerojet-General Corp.

I want to express my appreciation on behalf of the Aerojet-General Corp. for this opportunity to testify in behalf of President Johnson's accelerated program for development of water purification processes.

The Aerojet-General Corp. has been pleased to serve the U.S. Government, its principal customer, for over 20 years, primarily in the field of national defense. The company has made its greatest contributions over these years in the development of liquid and solid rocket engines, having held major responsibility for engines for the Polaris, Titan, Minuteman, and many other missiles.

Major contributions have also been made on other phases of the defense and space effort as a result of which there now exists within Aerojet a technological capability encompassing virtually all phases of scientific endeavor.

The growing need for pure water in the Nation and in the world has been so broadly publicized that it hardly needs further discussion. The 87th Congress of the United States demonstrated great foresight in its passage of Public Law 87-295, the Anderson-Aspinall Act, which accelerated the saline water conversion program in 1961.

The bulk of funds expended to date under that act has been devoted to research. As a result, important advances have been made on a broad front. Well-known processes have been improved to an extent that demonstrated costs in desalting water are only a fraction of that which obtained prior to the passage of that law. Virtually unknown processes have been developed to a point where further sizable cost reductions in water conversion are in sight.

The demonstration plant program has proved invaluable in providing both research and development tools and in demonstrating cost reductions resulting from laboratory and pilot achievements.

The demonstration plant program has pointed up those processes which warrant further pursuit and will ultimately expose those processes which should be abandoned. In all, the achievements in saline water conversion have been well worth the cost.

The long-range desalting program is approaching a milestone beyond which accelerated funding must be provided in order to bring past achievements to consummation. Research accomplishments of yesterday and today must be channeled into engineering development phases, which are inevitably more costly.

The bill now under consideration by the committee will provide the incentive and the necessary support for progressive pursuit of the objectives and has the unqualified endorsement of the Aerojet-General Corp.

The history of the reverse osmosis process, and the role of the Office of Saline Water and the Aerojet-General Corp. in its development, present a typical example of a process brought from virtual anonymity to the threshold of fruition.

Also illustrated in this example is the efficient operation of the Government agency-industry team in bringing about the achievements.

Mr. Chairman, before I turn over to Dr. Keilin for the balance of our presentation, I would like to add that our company's relationship with the gentlemen who are responsible for the Office of Saline Water has been excellent. We find them very diligent workers, the people both in Interior and the Office of Saline Water, and we are very proud to be part of their team.

Thank you, sir.

Senator ANDERSON. I am glad to hear you say that because those people in the department recognize the position that Aerojet-General maintains in many fields and we are glad to have your testimony here that they are doing a good job. I think they are, and I am happy you are cooperating with them. I hope it benefits you as it does them.

Mr. KEILIN. Thank you, Mr. Chairman.

About 5 years ago, the Aerojet-General Corp. undertook to diversify its product line into areas not associated with national defense. Geared to carrying out services under contract to the Federal Government, and ever responsive to national needs, the company sponsored an intensive study of methods for water purification. These studies indicated to us that the reverse osmosis process was sufficiently outstanding among the known processes to warrant intensive examination.

Subsequent study in research, development, and equipment fabrication has fortified our original conviction so that we now believe that for many applications, the reverse osmosis process will provide the lowest cost manufactured water for the future. This work has been

carried out both with company funds and with support from the Office of Saline Water, which has administered our programs with intelligence and with high regard for national objectives. As a result, the reverse osmosis process has moved close to fruition. I would like to digress and say this process is distinctly different from the electro-dialysis process.

Let me now briefly describe the reverse osmosis process which is shown on chart 1. A synthetic membrane, similar to cellophane, selectively permits the passage of water through the membrane, but does not permit the contaminating dissolved materials to pass through. Thus, a contaminated feed stream flows under pressure across a membrane surface whereupon potable product water is obtained on the downstream side of the membrane, and a concentrated reject stream remains behind and is discarded.

The membrane acts virtually as a magic door permitting the passage of that which it is desired to recover, rejecting that which it is not desired to recover.

The driving force is the pressure applied and the main advantages are derived from the process operation at ambient temperatures, requiring no boiling or freezing of the feed stream.

Selective membranes are common in nature. The root hairs of trees and plants are lined with selective membranes which permit water and essential minerals to be absorbed into the plant as required, but do not permit the loss of sugars and other compounds essential to the life of the organism.

Similarly, all animal cells are lined with selective membranes; the human kidney, for example, utilizes membranes to select those constituents of the body fluids which will be rejected and those constituents which must be retained.

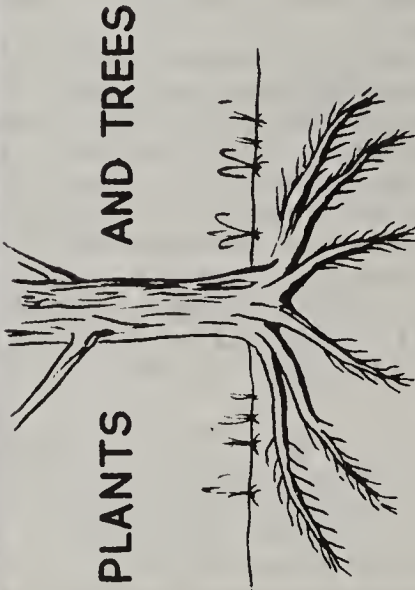
Reverse osmosis is not new, the basic principle having been described by Aristotle for purification of sea water. The process has been discussed again and again since the days of Greece as theoretical curiosity. It remained for Prof. C. E. Reid, under contract to the Office of Saline Water, to demonstrate that ordinary cellulose acetate (rayon) film exhibits adequate separation efficiency for an effective process, but at low throughput per unit membrane area. Somewhat later, Dr. S. Loeb, at the time a graduate student at U.C.L.A., modified the process for fabrication of cellulose acetate membranes to enhance the water throughput rate to economical levels while still retaining a sufficiently high rejection of the dissolved contaminants to render the product potable.

Shortly afterward, Aerojet-General undertook to improve the performance of these membranes, to develop new and better membranes, to demonstrate the feasibility of reverse osmosis in the field and to design low-cost equipment for economical application of the process. As a result, important advancements in the state of the art have been made, both in membrane improvement and in pilot development of the process.

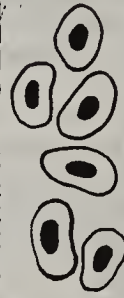
In all of these endeavors, Aerojet-General's relationships with the Office of Saline Water have been uniformly productive and fruitful.

Since award of our first contract in reverse osmosis by the Office in July 1962, the programs have been managed with resourcefulness, helpful guidance, and encouraging stimulation for the staff which Aerojet has brought to bear on the development of this process.

OSMOSIS IS A NATURAL PROCESS

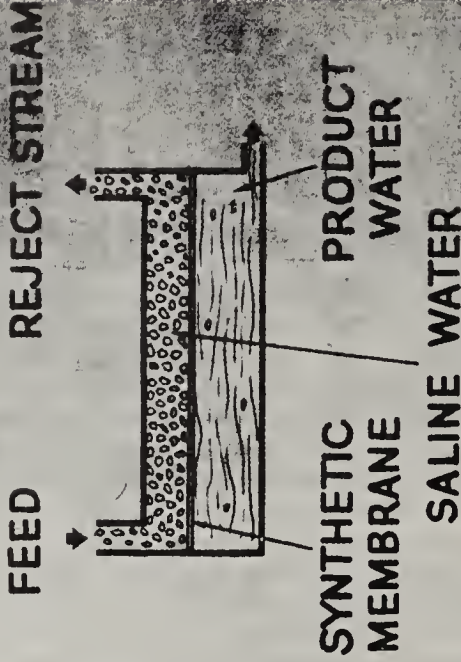


ANIMAL CELLS



LIVING MEMBRANES
ARE SELECTIVE

REVERSE OSMOSIS IS A SIMPLE PROCESS



SYNTHETIC MEMBRANES
ARE SELECTIVE

The unique membranes utilized in the reverse osmosis process resist the passage of most dissolved contaminants. As a result, the process promises to be useful in a variety of applications. The rejection of ordinary salinity, the major sea water contaminant, and of hardness, scale and alkalinity factors, predominant in many brackish waters, make its use obvious for such purposes. Furthermore, the membranes hold back organic matter, which is a major constituent of waste water and includes detergents. The membrane also rejects bacteria and virus so that the product is sterile. Mine drainage water may also be purified by this process as well as water contaminated by chemical, bacteriological, and radioactive agents. Specialized military uses include production of drinking water and boiler feed water; recovery of photographic wash water and laundry water; and disposal of shipboard wastes in harbors.

The problem of water purification is a problem of cost. The number and variety of technically feasible processes are almost limitless. However, economic feasibility is only coming into sight. To illustrate the problem (chart 2), note that the cost of Colorado River water in Los Angeles County, a high water cost area, varies up to about \$50 per acre-foot, or roughly $3\frac{1}{2}$ cents per ton, not including distribution cost. By comparison, the cheapest mined or manufactured chemical that can be purchased in the marketplace today is coal, for which a typical price is some \$4 per ton. Present normalized desalination cost, and I have particular reference to the demonstrated cost in the San Diego demonstration plant, sized at 1 million gallons per day, is roughly \$360 per-acre foot, or 27 cents a ton. In that plant, water—a “manufactured” chemical—is produced at less than a tenth of the cost of any other produced chemical today. This in itself is an incredible achievement and yet, that cost is 10 times the cost of Colorado River water in California.

Consider now the elements of the \$360 per acre-foot cost experienced in the San Diego demonstration plant—chart 3. Fuel and raw materials cost roughly 40 percent of the total; amortized capital cost is slightly over 25 percent of the total; maintenance and operations account for 18 percent, and taxes, interest, and general administrative costs 17 percent of the total. This, then, illustrates the principal points of attack at which efforts at cost reduction must be addressed.

Virtually all of the advantages of the reverse osmosis process derive from its room temperature operation. There is required no intermediate formation of steam or ice which, for the distillation and freezing processes respectively, leads to the expenditure of large quantities of energy. Reverse osmosis, on the other hand, requires only pressurization energy and the energy cost is relatively low. Furthermore, there is virtually no scaling and little corrosion, as a result of which the maintenance costs are projected to be low; these advantages combine to promise an extremely low total operating cost.

A further advantage of the room temperature operation is that the designer is able to use plastic materials, which are not capable of withstanding the high temperature demanded by the distillation processes. The use of plastic materials also enables the use of inexpensive fabrication techniques which lead to low capital costs and low taxes, interest and related general costs. Thus, each of the four elements which contribute to present desalination costs promises to be materially

**THE PROBLEM OF WATER IS A
PROBLEM OF COST**



3 1/2 ¢ PER TON
OR
\$ 50 PER ACRE-FOOT

NATURAL SOURCES



27 ¢ PER TON
OR
\$ 360 PER ACRE-FOOT
PRESENT DESALINATION
METHODS
(1,000,000 GAL / DAY)

Chart 2

THE ELEMENTS OF COST IN DEVELOPED
PROCESSES ARE MANIFOLD

CAPITAL	1,000,000 gal/day
	\$ 95/ACRE-FT
FUEL AND RAW MATERIALS	140
MAINTENANCE & OPERATIONS	65
TAXES, INTEREST, GENERAL	60
TOTAL	\$ 360/ACRE-FT

Chart 3

lowered in the reverse osmosis process, primarily as the result of its operation at ambient temperatures.

Let us now consider a translation of these various advantages into dollar-and-cent projections. The costs which I presented for state-of-the-art distillation systems were for existing 1-million-gallon-a-day plants. When these costs were projected to 10-million-gallon-a-day plants by various architect-engineering companies, it was estimated that the costs would be reduced for sea water systems to approximately \$235 per acre-foot (chart 4), a cost reduction which derives primarily from increase in plant size.

These estimates and all others presented herein have been calculated in accordance with the standard procedure developed by the Office of Saline Water for such purposes. By comparison, the cost projection for reverse osmosis in a 10-million-gallon-a-day sea water plant is \$143 per acre-foot, the major portion of the comparative difference in cost being derived from lower energy cost. I hasten to add that this projection to a 10-million-gallon-a-day plant is a long extrapolation from the 1,000-gallon-a-day plant that we now have in operation. Nevertheless, such a promising cost projection surely warrants vigorous scale-up of the process in an attempt to bring such cost improvement to fruition.

Reverse osmosis promises to yield even greater cost savings in application to lower salinity systems—brackish or waste water. In utilization of distillation processes for desalination of low-salinity waters, costs are not greatly reduced compared to sea water. In the case of reverse osmosis, however, a further major improvement is derived both in capital cost and in fuel cost, which results in a projection in 10-million-gallon-a-day plants of \$68 per acre-foot. This latter number begins to approach the cost of water from natural sources in many areas of the United States. Thus, impetus for aggressive development of this process is provided further.

Senator ANDERSON. That figure of \$68 is compared with the \$50 figure that you used a while ago?

Mr. KEILIN. Yes, sir.

Calculations on cost have been made with the assumption of existing prices for fuel, as set forth by the Office of Saline Water standard procedure. Should a less costly fuel source become available, as from a large nuclear powerplant, reverse osmosis costs would benefit as would any other process. Indeed, the reverse osmosis process is particularly suited to matching, in dual power/water plants, with a nuclear energy source. It has recently been calculated that, matched to a given nuclear powerplant, more water could be produced at less cost for a given level of marketable power than could be produced by a distillation plant. Furthermore, because the reverse osmosis plant operates on electricity, not steam, it would not be necessary to locate a huge desalination plant at the powerplant site. Small reverse osmosis plants could be located at the place of water need and operated on transmitted power from a large nuclear-power producing plant.

In developing the reverse osmosis process to its present state, Aerojet's efforts have not been limited to the laboratory. One of the most important steps in the development of any chemical process is that first one which moves the process from the laboratory into a working field model. This step, again with the helpful guidance and funding

COST PROJECTIONS ARE PROMISING

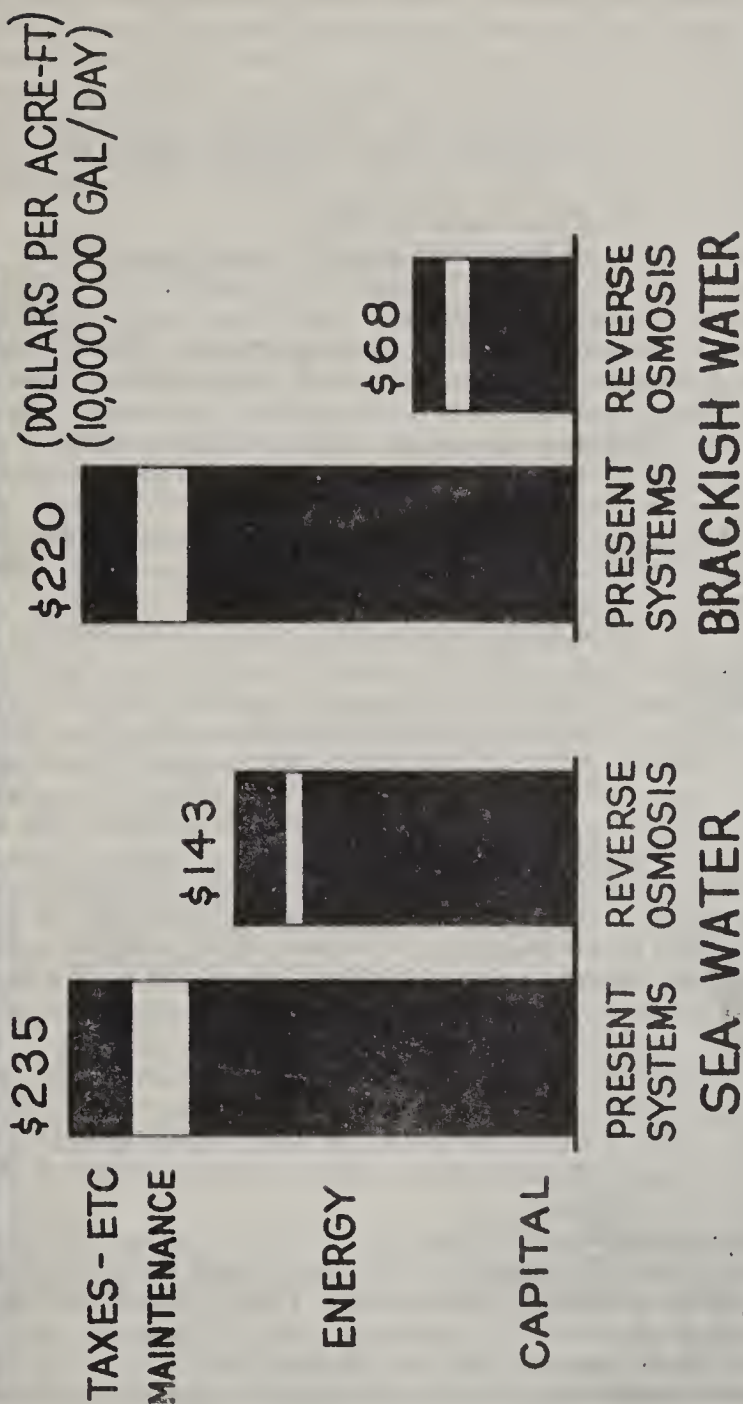


Chart 4

of the Office of Saline Water, has been achieved with great success. Engineering experiments have been carried out in a 1,000-gallon-a-day pilot plant, operating on various brackish waters containing 5,000 parts per million, 0.5 percent, for over 2 years. The work has culminated recently in a continuous 51½-month test, exhibiting low maintenance and operational requirements. Operations on sea water at the 1,000-gallon-a-day level have recently been initiated. On a smaller scale, the utility with sewage waters has also been demonstrated under contract with the Public Health Service.

One of the most important aspects of developing the reverse osmosis process to its ultimate is the low cost manufacture of the membranes. The membranes are unique and require an unusual fabrication procedure. Aerojet has, with its own corporate funds, developed a continuous process for manufacture of high quality membranes at low cost. We are now capable of supplying the needs of the Nation for membrane for many years of utilization of this process.

The program has been of such high success that the project is ready to proceed to larger experimental plants. With the support of this committee and the U.S. Congress for President's Johnson's program, the Aerojet-General Corp. is prepared to serve the Office of Saline Water by construction of a 50,000 gallons a day experimental plant to operate on brackish water. This could be undertaken immediately and awaits only available funds. Similarly, we expect shortly to be ready to move ahead in the area of sea water purification on a larger scale. The renovation of sewage wastes is now ready to be moved from the laboratory where it has had a most successful preliminary feasibility study and into the field in a 1,000 gallons a day plant to demonstrate utility in actual operating conditions just as has already been done in the brackish water applications.

There is much to be done in improving the process. The surface has only been scratched. It might be pointed out, for example, that only a very small fraction of 1 percent of the funds which have been expended in developing the distillation process over the years, has been spent to date developing reverse osmosis. There is a great future in research on new membrane systems which will lead to even greater performance and economy. It is our firm belief that, with support of this program in the manner that it warrants, vast improvements will be effected in the state of the art of desalination technology and that it will be brought about by the reverse osmosis process. I thank you for your kind attention.

Senator ANDERSON. Thank you, Mr. Keilin, and Mr. Gore, for your presentation. I think that this shows that there are still firms that have faith in their own processes. I have found out which would be the best many times this morning. And I think that is what we need, the ability to demonstrate what can be done.

I hope you won't mind if we send you some questions later on to be answered if the staff finds it necessary.

Thank you both for being here.

I think the last speaker is Mr. Ken Davis of the Bechtel Corp.

He doesn't seem to be here.

We will adjourn until 10 o'clock tomorrow morning.

(Whereupon, at 12:40 p.m., the subcommittee adjourned, to reconvene at 10 a.m., Wednesday, May 19, 1965.)

SALINE WATER CONVERSION

WEDNESDAY, MAY 19, 1965

U.S. SENATE,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 3110, New Senate Office Building, Senator Clinton P. Anderson presiding.

Present: Senators Jackson (chairman of the full committee), Anderson (chairman of the subcommittee).

Also present: Jerry T. Verkler, staff director; Theodore M. Schad, consultant; and Richard N. Little, minority counsel.

Senator ANDERSON. Our first witness this morning is James T. Ramey, Commissioner, Atomic Energy Commission. We have had many years of joint acquaintance on the Atomic Energy Commission. We are happy to have you here today.

STATEMENT OF COMMISSIONER JAMES T. RAMEY, U.S. ATOMIC ENERGY COMMISSION; ACCOMPANIED BY DR. JOHN SWARTOUT, ASSISTANT GENERAL MANAGER FOR REACTORS; W. A. WILLIAMS, JR., CHIEF, DESALINATION BRANCH, DIVISION OF REACTOR DEVELOPMENT AND TECHNOLOGY; AND DR. R. PHILIP HAMMOND, OAK RIDGE NATIONAL LABORATORY

Mr. RAMEY. Mr. Chairman, I have with me Dr. John Swartout, our Assistant General Manager for Reactors, and Mr. Bill Williams, who is in charge of our desalination branch, and Dr. Phil Hammond, with whom I know you are acquainted and who heads up our work at Oak Ridge. I thought it would be useful to have them with me.

Senator ANDERSON. I am particularly happy to have Dr. Hammond here, because as far as I am concerned, the first suggestion I had on nuclear energy and desalination came from his fine paper in 1955.

Proceed.

Mr. RAMEY. I appreciate the opportunity to appear before this committee to review briefly what the Atomic Energy Commission is doing to make possible the use of nuclear energy for desalting sea water. It is a pleasure to be able to discuss the AEC's activities in this area with you today.

For nearly two decades, the U.S. Atomic Energy Commission, in cooperation with industry and with the encouragement of Congress, has been developing nuclear systems for peaceful purposes. During the past decade, in particular, we have devoted considerable effort to

the advancement of reactor technology for the generation of electricity in the United States and the world. Our program goal of economic generation of electricity by nuclear means is nearing realization in many areas of the United States.

As members of this committee, you are aware that the energy demands in this country over the next 25 to 30 years are bound to increase enormously, because of the increasing population and industry, together with the increased use per capita. Thus, in the coming years we shall need all the energy we can produce from all sources of fuel. We in the atomic energy program are proud that nuclear energy will be taking its place alongside the fossil fuels—oil, gas, and coal—and hydro in helping supply this large energy demand.

The potential of tying in nuclear energy with the desalting of sea water was recognized as far back as 1955. Senator Anderson, you will recall that when you were chairman of the Joint Committee on Atomic Energy at that time, you requested our Los Alamos scientific laboratory to advise you on the long-range potential for using nuclear energy for desalting water. Dr. R. Philip Hammond, now at our Oak Ridge National Laboratory, but then at Los Alamos, indicated that the heat from nuclear reactors could be use to distill sea water and that the unit cost of the energy would decrease significantly with the increasing size of nuclear plants.

In the late 1950's, a development and design effort related to process heat applications for paper manufacturing and food processing resulted in congressional authorization for a low temperature process heat reactor. Due to the small quantity of energy required by process heat users, no potentially economic process heat application was found.

Initial plans for a sea water distillation plant utilizing a nuclear heat source were formulated in 1959 by the Department of Interior and the Atomic Energy Commission. This plant contemplated the construction of a small experimental process heat reactor coupled to a 1-million-gallon-per-day demonstration multistage flash sea water distillation facility.

Unfortunately the reactor portion of the project did not go forward because of siting difficulties. Subsequently, the Department of the Interior built what proved to be the highly successful Point Loma distillation plant with a fossil fuel heat source.

Interest in nuclear process heat for desalting did not increase again until recently when the scale-up of nuclear power plants made energy costs less expensive. In this interim period, the Commission's civilian nuclear power program made substantial progress in furthering the technology and construction of large-size, light, water-cooled nuclear power plants, as well as smaller prototypes involving more advanced concepts.

An indication of this progress is reflected by the fact that five light water-cooled nuclear power plants over 400 megawatts electrical in size are currently under contract for construction with power costs from 4 to 6 mills per kilowatt hour. Also significant is the construction of power conversion facilities for utilizing energy from the new production reactor at Richland, Wash. This facility will be capable of generating 800 megawatts of electricity and is scheduled for completion late this year.

In 1962, Dr. Hammond recalculated some of his earlier work and published his results in conjunction with the Oak Ridge National Laboratory. This work attracted the attention of the Presidential Office of Science and Technology. Dr. Wiesner, then the Director, appointed an ad hoc task group to investigate the thesis that energy costs from very large reactors would be low enough that fresh water could be produced from sea water economically by distillation processes. Staff of the AEC, the Federal Power Commission, and the Department of Interior—including the Office of Saline Water and the Bureau of Reclamation—were on the task force. Commissioner Wilson and myself represented AEC. We had meetings for a little over a year and issued our final report in March of 1964.

Last July, as you know, President Johnson requested the Department of Interior, in close collaboration with the AEC, to prepare a plan for an aggressive program for the large-scale desalting of sea water. Again Interior and AEC staff worked in close cooperation to develop the report to the President on a program for advancing desalting technology, which was released in late October.

PROGRAM FOR USE OF NUCLEAR ENERGY FOR DESALTING

The AEC's program for developing suitable energy sources for desalting, as set forth in the report to the President, has two major areas of endeavor.

The first one is to provide appropriate nuclear energy sources to meet desalting needs during the next 5 to 15 years. We will do this by determining the most efficient methods of combining proven nuclear reactor systems with desalting plants.

The other, which is a longer term program, involves the development of engineering and economic data, and the operation of suitable prototype plants which will permit us to determine the best nuclear reactors for the longer range use as energy sources for desalting plants producing several hundreds of millions of gallons of fresh water per day. This latter part of our program is aimed at developing engineering and economic data by the mid-1970's to determine the optimum nuclear energy sources for large-scale desalting plants beyond 1980.

With respect to our near term program, we now have nuclear powerplants, commercially available, which can provide energy for water desalting plants in dual purpose installations. However, no practical experience has been obtained in the design, construction, and operation of reactors for this purpose, particularly in regard to the coupling of the two systems. Therefore, investigations of various aspects of reactor and powerplant design are being conducted to determine the best sizing, operating characteristics, and economics.

We are also conducting engineering and economic studies for specific locations jointly with Interior. These include the joint studies we are conducting with the Metropolitan Water District of California and with the Government of Israel. General systems analyses are being conducted at our Oak Ridge National Laboratory and by selected contractors.

We are also endeavoring to establish the advantage of applying current reactor technology in modified systems designed to provide energy

at temperatures directly applicable to single-purpose water distillation plants.

To meet the long-term needs for nuclear energy sources for large-scale desalting plants, we are investigating the potential of reactor components ranging in size from 3,500 to 10,000 thermal megawatts.

The feasibility of scale-up to large sizes, the economics of such systems, and the special design advantages resulting from dual-purpose applications are being examined.

The reactor concept which we have identified as the leading candidate for use in the long-range desalting program is the heavy water organic cooled reactor. This reactor's prospects for producing very low-cost energy, for efficient use of nuclear fuel, and for practical use in large single unit sizes makes it promising whether used in power only or dual-purpose plants.

Our current planning for our civilian nuclear power program includes a 1,000 thermal megawatt prototype of this concept for operation in the early 1970's. This prototype will be designed to produce about 300 megawatts of electric power, and is expected to demonstrate the technical feasibility of this particular concept.

The next logical step would be the combining of a heavy water organic cooled reactor with a desalting facility to produce both electric power and fresh water. Our present planning calls for the construction of a reactor of about 3,500 thermal megawatts, with an output of electricity of about 500 megawatts electric and 300 million gallons per day of water. This plant would begin operation in the 1975-78 time period.

We have initiated a study of the siting and operational problems of very large-size nuclear energy systems for dual purpose application. We are also investigating the technical feasibility and economic advantages of combining other industrial processes with desalting plants to improve the overall economics of the use of nuclear power.

INTERNATIONAL PROGRAM

President Johnson on several occasions has expressed his support for sharing the benefits of American desalting technology with other nations. For example, in a message to the delegates to the Third Geneva Conference on the peaceful use of atomic energy last September, he said:

Our Government is proceeding with an aggressive program of nuclear desalting. What we learn in this program will be shared with other nations. Already we have begun cooperative exchanges with Mexico, with Israel, and with the Soviet Union. Today, I invite all of you to join with us in this enterprise.

The International Atomic Energy Agency (IAEA) has been the focal point for the AEC's international cooperation in this field, along with, of course, the Department of the Interior. The IAEA, an international organization established in 1957 to promote the peaceful uses of atomic energy, has taken an active role in evaluating the possible application of nuclear energy to desalting.

In early 1963 the IAEA convened a panel to advise it on the status of water desalting technology and on the general merit of using nuclear reactors as the energy sources for desalting plants. Over the past 2 years, 5 panel sessions have been held, and representatives from

about 25 countries have attended. It has been my pleasure to work in close collaboration first with former Under Secretary James Carr of the Interior Department and later with Assistant Secretary Kenneth Holum as the U.S. representatives to these sessions.

We have been reviewing the needs and potential for nuclear desalting in Israel, Tunisia, and the United Arab Republic in cooperation with those countries.

The United States and Israel have completed a preliminary survey of Israel water and power needs, and a detailed engineering and economic study is in progress. The preliminary survey indicated that a dual-purpose nuclear plant producing 100 to 150 million gallons per day of water and 175 to 200 megawatts of electricity may be economically attractive for Israel power and water needs.

Discussions are being held regarding a proposed cooperative study with Mexico in which both the AEC and the Department of the Interior would participate, and which would be conducted under the sponsorship of the IAEA.

A technical team from Italy is presently visiting U.S. facilities and preliminary discussions regarding possible cooperation on desalting have been held.

We are participating in a program with the U.S.S.R. for an exchange of technical information in the desalting field, including the use of nuclear energy.

To insure that our international desalting activities are consistent with U.S. foreign policy objectives, the AEC, along with the Departments of Interior and State and other appropriate Government agencies, is represented on an interagency committee on foreign desalting programs.

AEC ORGANIZATION FOR DESALTING

The development of nuclear energy for desalting has strong Commission support. Responsibility for policy-level coordination has been retained at the Commission level. A Desalination Branch has been established in the Division of Reactor Development and Technology to handle the day-to-day administration and implementation of the AEC's program. The Desalination Branch Chief reports to the Assistant Director for Civilian Power who is responsible for developing civilian nuclear power reactors, and coordinates nuclear desalting technology with the technology arising from the other reactor development programs.

The AEC's Oak Ridge National Laboratory has been assigned a major role in the AEC's research and development program for the application of nuclear energy to desalting. An experienced group of scientists and engineers is working at Oak Ridge in several of the areas which I mentioned earlier. We are also utilizing ORNL as a technical extension of our Reactor Desalination Branch in conducting the overall AEC program.

The talents of our other national laboratories and industrial contractors will be used in performing part of the work in our program.

The AEC and the Office of Saline Water recently completed arrangements for the use of the Oak Ridge National Laboratory and the engineering capabilities of the Oak Ridge gaseous diffusion plants on the desalting side of the technology. Under this arrangement, work

will be performed for the OSW on intermediate and large-scale desalting plants.

We in the Atomic Energy Commission are glad to participate in the joint nuclear desalting program. We are working effectively with the Department of the Interior in planning and initiating a coordinated development effort. The program which we are undertaking, when taken together with the program of Interior, provides a realistic path toward our objectives. With the continued support of the Congress and its appropriate committees our objectives can be achieved.

Thank you, Mr. Chairman.

Senator ANDERSON. On the top of page 6, you mention 300 million gallons of water a day. How does that compare with the current size of plants? For instance, the plant we shipped down to Cuba?

Mr. RAMEY. The plant that was moved from San Diego to Cuba was producing, as I understand it, around 1,400,000 gallons a day. So this would be a very large scale-up.

Senator ANDERSON. I think it was designed at about a million gallons a day and did develop some extra capacity?

Mr. RAMEY. Yes, sir.

Senator ANDERSON. I just wanted to point out it was 200 or 300 times as large as what we are producing.

Mr. RAMEY. Yes, sir.

Senator ANDERSON. Do you think the volume we are running through is going to be in some degree responsible for the reduction in price?

Mr. RAMEY. Yes, sir; we believe that the scale-up of the desalting technology should result in lower unit costs of the production of water. Of course, this is the bailiwick of my friend, Frank Di Luzio and the Interior people. But AEC has participated in these studies and we have gone through this scale-up process on nuclear reactors. We believe the problems on the desalting side probably are not as difficult or complicated as they were on the nuclear side. We do have a little bit of jump on them at this stage. We believe that with the proper amount of engineering effort and research, the desalting technology could jump forward quite rapidly, and then on the nuclear side, we would have to be moving to catch up.

Senator ANDERSON. You are not in doubt about your ability to keep moving on it, are you?

Mr. RAMEY. No, sir. We have a program that we have laid out whereby we think we can, through these prototype plants, be able to demonstrate and determine the economics of the very large scale nuclear desalting combinations. But we do have to get moving. We have to get to the hardware stage. None of these dual-purpose plants have been built yet.

Senator ANDERSON. I wonder if Dr. Hammond would like to say a word or two about that.

By the way, Doctor, I read your paper. I guess you wrote it in 1954, and it reads better now than it did then.

What are you looking for in sizes and in cost? Have you any idea? I am not trying to commit you to what your costs are going to be, but what your goals are.

Mr. HAMMOND. I think the program that has been laid out is a very effective one and the costs of water that we can foresee will relatively solve the goal for municipal and industrial water.

My own personal goal is not to stop there but to continue to work toward the goal of agricultural water. I think this is an attainable goal, but much farther off.

Senator ANDERSON. You have to go quite a way to get there, but you think it is attainable?

Mr. HAMMOND. That is right.

Senator ANDERSON. Senator Jackson?

Senator JACKSON. Mr. Ramey, or whoever wants to respond to this, I realize that it is depending on how it is charged off, but do you have any idea as to what the power costs will be when we are talking about a 300-million-gallon plant? What are your projections on that without getting too far out on the end of a limb, and what do you think your water costs will be if you can give a curbstone statement?

I fully realize that it involves the economics, how you want to set it up bookkeepingwise, but could you give us some sets of variables so we could see in what direction we are going?

Mr. RAMEY. We have done several engineering studies in some depth and the first study in that depth was this Office of Science and Technology interagency committee study, in which we did look at the very large size plants. There, for example, we were really looking at plants that would produce water in somewhat larger amounts and also using reactors of more advanced technology. We took as a reference design, however, a plant that would be built using current reactor technology and just scaling up the current desalting technology. So perhaps I might start with that one.

That would be a plant that would produce approximately 180,000 kilowatts, 180 megawatts of electricity, and produce 170 million gallons of water a day. In such a facility, the estimated power value, the amount that it was thought a comparable size power-only plant would produce, the value was used as 4 mills for the power. The cost of water that would be produced was estimated at around 33 cents a thousand gallons.

Then, when you begin to scale up the plants, we took as a reference design the case of what we call the 6.6-1 case, a reactor that would produce around 1,400 megawatts of electricity and 620 million gallons of water—

Senator JACKSON. That is 1,400,000 kilowatts?

Mr. RAMEY. That is right. And the power value we used there was 2.4 mills per kilowatt hour and the water cost that we came out with was around 23 cents.

Senator JACKSON. How many gallons is that?

Mr. RAMEY. That is around 600 million.

Senator JACKSON. 600 million a day?

Mr. RAMEY. Yes, sir. So between that range, we took a heavy water reactor that would produce around 500 megawatts of electricity, 520 megawatts of electricity and would produce 310 million gallons of water a day and we estimated the power value would be around 3.2 mills and the water cost would be around 27 cents a thousand gallons.

Now, this was based on public financing for both the water system and for the energy plant at 7 percent.

Senator JACKSON. This also presupposes, in the case of water, I take it, that you connect up with the existing water system? It does not allow for the construction of the distribution system?

Mr. RAMEY. That is right. This is water at the site of the water-plant.

Senator JACKSON. Like bus-bar power?

Mr. RAMEY. Yes, sir.

Senator JACKSON. It is water available through the existing system or through the reservoirs?

Mr. RAMEY. Yes, sir.

Senator JACKSON. Is not a significant point here—it seems to me in listening to your very fine testimony that we really learn by doing. Much of this work involves engineering and the success of it as well as research.

Mr. RAMEY. Very much so; yes, sir.

Senator JACKSON. We have done a lot of research already, but is not the area of experience pretty crucial and quite vital in order to make these systems that are pretty well thought out researchwise to work in operation and to get the historical data so you know that it will do these things? This is what we lack; is it not?

Mr. RAMEY. Yes, sir; that is certainly true in this field of dual purpose plants that utilize the distillation process. I am sure Mr. Di Luzio will go into this. There are other processes, particularly on small-scale desalting plants, where more basic research is required. But the whole history of nuclear power has been that we have learned by doing and by going several different routes.

You will recall that back 10 years ago we started with the pressurized water reactor, following on our naval reactor experience, and went with Shippingport and then with Yankee and now with larger scale pressurized water plants.

Similarly, on the boiling water reactor, we built the experimental boiling water reactor at Argonne. This was followed by the Dresden plant by our friends at Commonwealth Edison outside of Chicago. Now, we have gone on to the Jersey Central plant which is under construction and which will produce power in a system at less than 4 mills.

Very recently, Commonwealth Edison has announced that they are going to build Dresden No. 2, which will produce between 700,000 and 800,000 electrical kilowatts and where the cost of power will be in this Jersey Central range.

Senator JACKSON. The large-scale undertakings especially offer the promise of reduction in cost for both power and desalting. If we can build them and get the experience from the operation.

Mr. RAMEY. Yes, sir. We have found this scale-up factor in the nuclear field is particularly important. That is because you do not incur a lot of extra cost for radiation shielding or for control systems or for a lot of other things, whether the plant is 400,000 or 800,000 kilowatts. So your unit costs of energy go down pretty rapidly as you increase above a certain size. We think that this scale-up factor will have some effect also on the desalting side.

Senator JACKSON. Mr. Ramey, I want to commend you and the Commission for the fine job you have done and are doing and the excellent cooperation that exists with the Department of the Interior and the other agencies affected.

This is all I have.

Mr. RAMEY. Thank you, sir.

Senator ANDERSON. I want to join with the chairman of the full committee in expressing that same appreciation. Those of us who have been thinking of this for quite a while, since 1955, for example, Dr. Hammond, thought it might be a matter of 25 years. It may still be that long, but the assurance of success is much greater now than it was in the beginning. We are all very happy with this work and we hope you will continue to be as successful in the future as you have been in the past. Thank you all very much.

STATEMENT OF DR. MYRON TRIBUS, DEAN, THAYER SCHOOL OF ENGINEERING, DARTMOUTH COLLEGE, HANOVER, N.H.

Mr. TRIBUS. I am Myron Tribus, the dean of engineering at Dartmouth College. I have spent more than 23 years in engineering, as a professor and as a consulting engineer. My clients have included various branches of the Government, the North Atlantic Treaty Organization, several departments of the General Electric Co., and other commercial enterprises. My publications and textbooks in engineering are in use in many countries. My interest in sea water conversion began in 1949, 3 years before there was an Office of Saline Water. From 1954 until 1961 my research in saline water conversion was sponsored by the State of California. In 1961 I left California for New Hampshire. Since that time my work has not been sponsored either by the State of California or the Office of Saline Water. But my students and I have continued to work on this subject.

The central subject of my inquiries has been the economic optimization of the various methods for making fresh water from the sea. My students and I have studied each method that has been proposed in order to see in what manner the methods might be improved and just what the ultimate potential of each method might be. The results of some of our work are contained in the several documents you see in this pile beside me. Based on these studies, which now span 15 years, I have come to several conclusions regarding the Federal program in desalinization as it has been carried on in the past.

In my testimony this morning I will make three points:

(a) The emphasis of the Federal program has been badly misplaced.

(b) There are very good reasons why the program has not heretofore been properly directed.

(c) There are some specific things which I hope the Congress will do to put the program on the right track.

The original legislation establishing the program in saline water conversion in 1952, and every subsequent piece of legislation, have left no doubt concerning the intentions of the Congress. Every piece of legislation contains the phrase "low cost." The central issue on this program is the reduction of the cost of water produced from saline sources. In this connection the program differs markedly from every other Federal research and development program. In the space race and in defense the objective is to accomplish a certain new and often hazardous mission, one in which cost is not the primary consideration. In no other American enterprise has the responsibility for reducing costs been located so centrally in an agency of the Federal Government.

Despite this difference, the activities, programs, and procedures of the Federal Office of Saline Water have been organized more or less to resemble activities of the Federal programs which have a much different objective. In order to make this point explicit, I should like to describe to you just one result from our work. The technical material I am about to present will be brief. It sets the stage for what I have to say later on.

I will depart a little bit from the material I gave you in the interest of saving time. You have before you, I believe, a transcript of what I have prepared for this hearing and you will notice that there is a figure 1. Since there are people in the audience who do not have that, if you do not mind, Mr. Chairman, I will sketch on that little sketch pad over here. The things I am going to say are rather brief, but they do set the stage for the points I wish to make.

Every process for making fresh water from the sea can be described by plotting on a graph the amount of energy per unit of water versus the rate at which you force water through the area that separates the fresh water from the sea water. If you make a graph for approximate purposes for our discussion this morning, it turns out that it looks more or less like a straight line. There may be some curvature, but that is unimportant. This says, in effect, whenever you have a plant and try to shove more water through it, it becomes less and less efficient and you have to use more energy to do the job. This is no different from driving your automobile faster and faster down the highway; the faster you drive, the more fuel you must use to go each mile.

What we are interested in, of course, is not the efficiency of the plant, but the cost of water, which means one must be concerned with trading capital and fuel—here is the plot now. The cost of the water, cents per thousand gallons or dollars per acre-foot. And you plot here the rate at which you try to shove water through the plant, then the cost of energy, which of course is just multiplying this amount of energy by so many dollars or cents per kilowatt, can go like that. But the capital cost of owning this plant begins to go down, in the sense that, if you are running a bus and hauling passengers, the faster you run, the more trips you can make, so your capital investment is diminishing. So you get a curve like this—this representing the capital investment and this representing the energy cost.

Now, the best way to run this plant—of course, you have to total these up—is to find the point on this curve which is at a minimum.

Over here [indicating right side of chart] we have a plant which is being used too inefficiently and costs too much money. Over here [indicating left side of chart] we have a plant which has been overdesigned and costs too much money because its capacity is not being fully utilized. The minimum cost plant is here [indicating].

(The charts referred to appear on p. 98.)

Mr. TRIBUS. The problem we set ourselves to is to determine what that minimum cost looks like and how it varies as the cost of energy, surface, treatment and so forth. It should be obvious to you that the proper design of each plant depends entirely on what you have to pay for the materials you use and how smartly you use them.

I shall not go through the details except to say, again I will repeat part of that first figure—there is the equation that describes this plant. It says that the energy per pound of water is some coefficient which we could call the resistance times the weight rate per unit area. If you

calculate that minimum point, it turns out to be that the minimum cost of water depends essentially on the square root of the cost of energy, the cost per unit area of the surface, and this resistance, divided by the lifetime of the equipment. It is a very simple equation and says if you want to reduce the cost of water from the sea, you have to buy the energy cheaper or you have to have cheaper surfaces or you have to have lower resistances of the surface for the fresh water to get through, or you have to have longer life.

But it tells you one important thing and that is the point I want to make. It does not do any good to change these things to make a surface which has a lower resistance but a higher cost or lower life. It is the combination which tells us whether we are making headway or merely making change.

I want to return to the three points which I said I would cover. The first point is that the emphasis of the Federal program has been badly misplaced. Consider, for example, part V, "Program for Advancing Desalting Technology." That part of the report discusses the work to be done in the improvement of the reverse osmosis system. If you will read that report, keeping in mind the simple analysis I have just made, you will see that there is no mention of the important factors which influence the economics of the process. For example, there are figures in the report concerning increased flux rates obtained with membranes. This corresponds to a decreased resistance in the membranes, but we are not told if the costs and the life of the membranes were altered in such a way as to provide more or less expensive water.

Under the heading of "Membrane Research and Development," the report gives a description of various factors which will be studied. Nowhere in this report, however, is there any evidence that it is appreciated that the factors must be combined in the manner indicated in the above simple equation. We can go on spending money forever, sir, without actually decreasing the cost of the resultant water.

Ever since the saline water program began I have been observing with a mounting sense of frustration and concern that publicity agents for both the Government and private contractors continuously announce a significant "breakthrough" by claiming that one or another of these factors has been altered. They never state clearly what has happened to the other factors. The result has been to mislead the public and, I fear, the Members of Congress.

As a matter of fact, I came in early this morning to read some of the testimony that was given in the hearing yesterday, when I was not here. I am shocked to learn that the head of a corporation which makes its living out of selling thermal powerplants would tell this Congress that half of the heat of a powerplant is wasted, implying that all they have to do is hook up a desalination power system to this wasted source of heat and run it. This is a misleading statement. It is well known, has been known for over a century and a quarter, that what it takes to drive these plants is not the heat but the available energy—that is, the ability of heat to motivate a change. This is not rejected in large quantities from plants.

The advantages to be gained from putting desalination plants and power-producing plants together does not stem from a reason like this. It rather stems from the possibility that we may make one or two pieces of equipment do double duty or we may be able to get rid

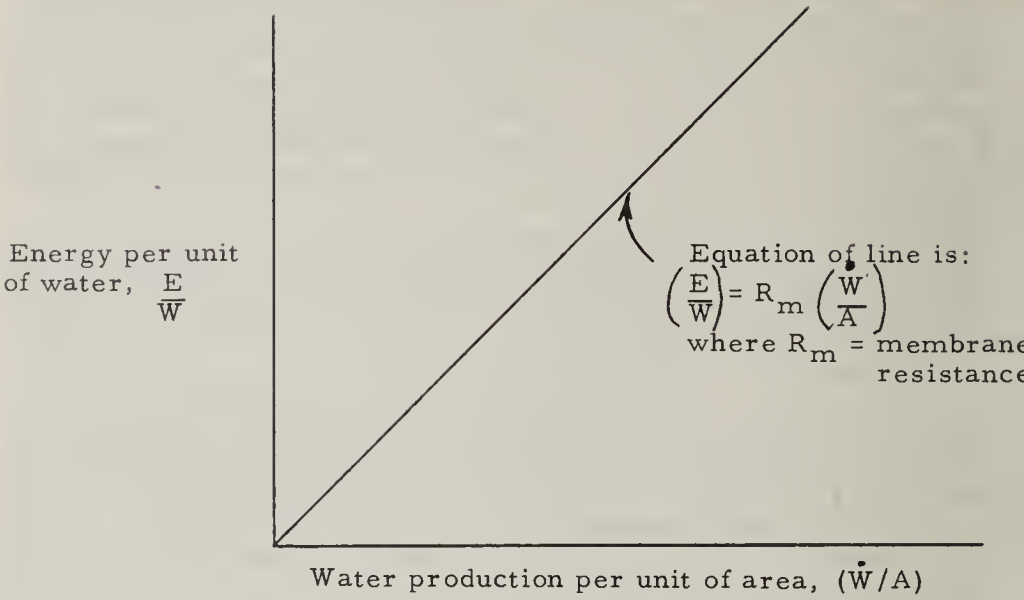


Figure 1

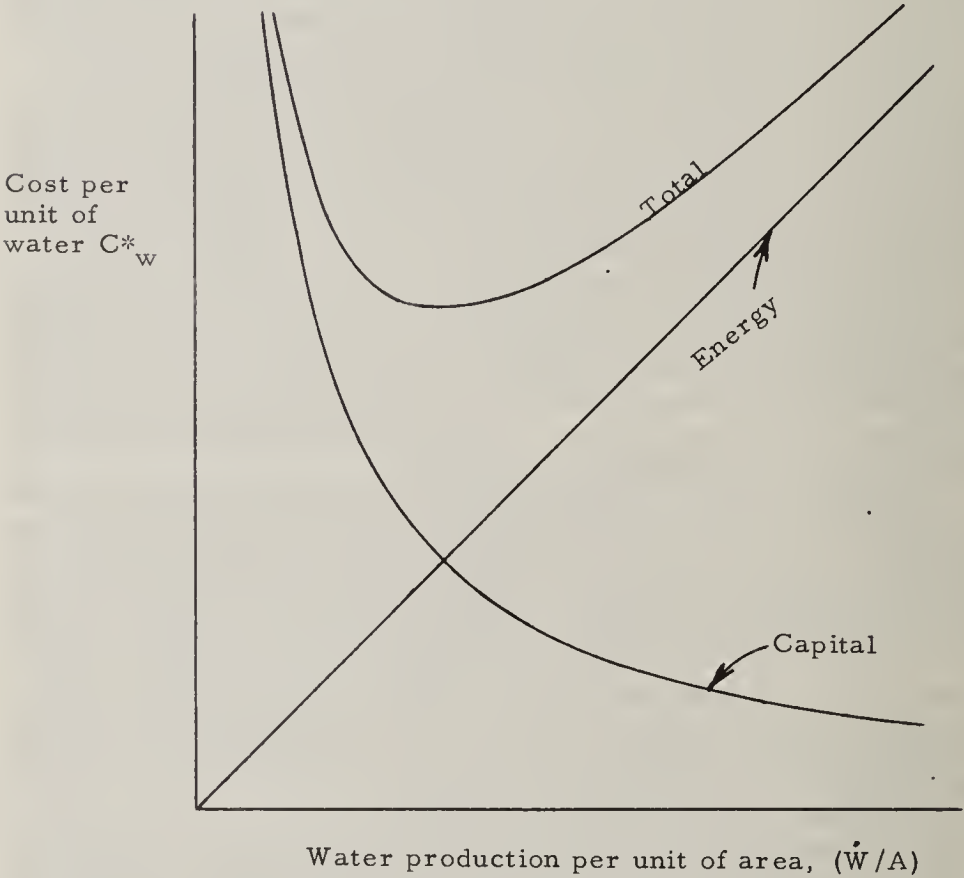


Figure 2

In this equation, the symbols mean the following:

- C_w^* is the cost per unit of water produced
 C_a^* is the cost of a square foot of membrane in place
 A is the area of the membrane
 L is the life of the membrane
 $\dot{W}$ is the rate of water production
 C_e^* is the cost of energy delivered to the surface
 E is the energy

From the equation on figure 1 we replace the last term

$$C_w^* = C_a^* \frac{A}{\dot{W}L} + C_e^* R_m \frac{\dot{W}}{A}$$

and from the calculus we find the minimum cost

$$C_w^*, \text{ minimum} = 2 \sqrt{\frac{C_a^* C_e^* R_m}{L}}$$

of, say, the expensive rear end of a steam turbine. These give you modest increments, but it is not at all a case of getting energy that is being thrown away. There simply is not available energy in significant quantities thrown away from these plants. That statement is misleading.

As another example, in the conclusion to part I of the report I have just referred to, we read the following: "The multistage flash demonstration plant built by OSW at San Diego was operated for 2 years and achieved a production rate 40 percent above design capacity." This is a misleading statement. As you saw in the last figure, there is an optimum operating point for every process. We can operate any plant in many different ways. To achieve increased production is not an accomplishment. What really counts is the cost of the water. Actually, my colleagues and I have published extensive analyses of this particular plant and it is our contention and no one has challenged it, although we have had the reports out over 3 years, that the plant was overcapitalized by about 30 percent in the first place. To refer to the increased waterflow as an achievement is to chase a false goal.

Because of the limitations of time this morning, I shall not continue to pile up example after example of how the Federal program has been carried out in almost total disregard of the lessons to be learned from this type of elementary analysis. I can assure you that, in view of the 13 years OSW has been in existence, I can produce examples of this sort for almost as long as you can afford the time to listen. I trust I have made the point that something significant has been lacking. I wish now to turn attention to why the Federal program has developed the way it has.

As I said in earlier remarks, the saline water program is in many ways radically different from other Federal research and development programs. Another distinction which must be made is that the leadership for this program has not been chosen the way we have chosen the leadership in other important research and development programs. In the Atomic Energy Commission, for example, we have always had topnotch men in the positions of technical leadership. Indeed, we have always had one or two Nobel Prize winners in the top-level planning of that Commission. The result, by and large, has been that we have seen first-class work from that body. Likewise, in the Space Agency we have recognized the need to place internationally known and respected engineers and scientists in charge. On the other hand, in the case of the Office of Saline Water, the appointments to the directorship have in the past, and I emphasize *in the past*, been made almost entirely on the basis of political considerations. The first director of OSW was a civil engineer who was replaced shortly after the program began. The second director of OSW used to say quite honestly in public that he was not really qualified for his job. He had been trained as an M.D. and after an unsuccessful bid for reelection to political office had been given the post. His replacement was also obviously appointed on primarily political grounds. We now have a fourth director recently appointed by President Johnson. I have met him and it is my judgment that the new director is fully qualified for the task and if given the right sort of support and the right climate, will bring to this Congress a sensible program which can advance the cause of sea water demineralization. But the materials that are brought to us now were not prepared under his leadership and they were put together by others. They do not represent a good, low-cost, saline demineralization program.

If the water problems were not so laden with political and emotional considerations, it might not have been so important to have had adequate technical leadership. Unfortunately, as I study the record, I can only come to the conclusion that the Congress and the country must be protected from natural inclinations to think that we can solve this problem simply by pouring in more money. The flow of fresh water is not going to be proportional to the flow of money. Indeed, I think perhaps the reverse could possibly take place. Again, I wish to depart from my prepared statement. I remind you that in the case of aviation, in the lifetime of the members of the committee, the Russians built a huge 12-engined airplane called the Do-X and flew it to this country. It was a huge biplane with 12 engines and at that time represented an enormous advance in aviation. But what made the aviation industry go? It was Douglas, building not a 12-engine airplane, but a DC-2 and DC-3, which were available to airlines, which they could afford, and which managed to make this country have a booming airline industry. I would point out when you have a government-owned and operated demonstration plant, you do not get relevant economic data. The way to get economic data on these plants is to design plants in the marketplace. Then the engineers build into the plant the features needed. When you build a demonstration plant, you simply demonstrate that you can do what you said you could do as far as making the thing go. But nobody is ready to believe or disbelieve the economic features because they represent an artificial situation.

If we swamp our talent with unrealistic and unlikely projects we may, in fact, decrease our chances of success. This warning is not new before this committee. For example, during the hearings in August of 1961, Senator Allott said :

I am afraid of going ahead a bit too fast on the construction of various plants well beyond the strictly pilot stage before we have proven out any generally successful method.

At several times during these hearings he asked some significant and pertinent questions but I am sorry to say that the general advice he received from most of the people who appeared before the committee was not sufficient to change the course of events.

In 1963 an article in Chemical and Engineering News, obviously submitted by the Public Relations Department of the Federal Office of Saline Water, begins in the following way :

Now that the Department of Interior's Office of Saline Water has constructed or contracted for all of the plants scheduled under its initial demonstration plant program, increased emphasis will be placed on basic research in water technology.

In short, this is an admission that, now that we have built the plants, we are going to do the research we should have done before we built these plants. The program that has been followed is completely reversed compared to the way an engineer responsible to stockholders would proceed to spend money. I consider it a failure of the engineering profession that we were not competent enough to redirect the program in 1961. The sad fact is that some very good questions put forth by Members of the Senate were answered rather badly by the witnesses and as a result the taxpayer's money has been wasted.

Part of the difficulty stems from the fact that this Nation is now in its 23d year of defense-type spending. Nearly a quarter of a century of cost-plus engineering has had a very strong effect on both engineering education and engineering practices in this Nation. In times of war and in matters of national defense we perhaps have no choice, and in matters involving totally new experiences, such as some forms of nuclear reactors or some forms of use of nuclear power or voyages into space, there is a need for extremely expensive experimentation. But in sea water demineralization we are not venturing into entirely new territory. We can duplicate at much less cost, and in smaller scale in our laboratories, all of the important things we need to learn. As a matter of fact, one of the people said in behalf of his corporation, "We are ready now to build 150-million-gallon-per-day plants." I think he is. Why are we going to build for the Government a 50-million-gallon-per-day plant? Are we going to save enough money on that 150-million-gallon-per-day plant to pay for the cost of the 50-million-gallon-per-day plant?

Senator ANDERSON. Do I understand you would not build the 50-million-gallon-per-day plant or would not build the 150-million-gallon plant?

Mr. TRIBUS. When I come to the end of my testimony, I will respond to that, sir, if I may.

Senator ANDERSON. All right.

Mr. TRIBUS. I am sure you know that parents can ruin their children by giving them unlimited allowances. In like manner you can ruin these engineering endeavors by supporting them too lavishly. When

we know that a particular process for making fresh water from the sea is not economically attractive, what do we possibly gain by building a demonstration plant? If we lose a little bit on every gallon of water, we certainly can't hope to make it up by large volume.

In the spring of 1962 I visited Washington for a day to discuss these matters of economics with one of Secretary Udall's advisers. In his own field of science he is quite competent, but, like many of our scientists, he has a lot to learn about economics. I spent the entire day telling him about the way in which the economic and technical factors must be balanced if we are to make progress in the reduction of the cost of making fresh water from saline water. In March 1964 there appeared a report of an interagency task group, "An Assessment of Large Nuclear Powered Sea Water Distillation Plants." The equations I had taught this fellow to use were repeated on page 27 of that report and, unfortunately, badly misinterpreted as a careful study of that part of the report will show. The error is repeated in connection with the arguments used to justify the reverse osmosis scheme in the second sentence of part V of the report "Program for Advancing Desalting Technology," which reads:

This is so because the system is inherently simple and, unlike many other processes, no phase change is involved, reducing energy costs to an extremely low value.

That statement is false. I remember particularly well trying to prevent the consultant from falling into the trap of thinking this was true. What disturbs me is that we have not had in OSW anyone of sufficient stature and competence in the field of thermodynamics and economics that errors of judgment of this kind could be prevented. Other comments which are equally revealing appear throughout the document and it is this fact which prompts me to urge you to make some changes in the pending legislation.

I trust that by now I have made the first two of my three points; namely, that the emphasis in our program has been misplaced and that there is a good reason for this misdirection. I now wish to turn our attention to what ought to be done about it. I propose to you that you modify the pending legislation in three important ways.

(a) First, I propose that you create an Advisory Commission on Saline Water Conversion.

The Presidential Science Advisory Committee has strongly urged that every department of the Government engaged in research and development work ought to have an advisory committee which reviews the R. & D. programs of that department. The committee I have in mind ought to have on it men of unquestioned technical abilities. They ought to represent the disciplines of economics, chemistry, chemical engineering, mechanical engineering, civil construction, and operations research. The committee membership should include men of experience in water distribution, power production and sales, and in the development of chemical process equipment, such as, for example, is represented by the oil refineries. This commission should be nonpolitical in character, as are so many of the other advisory committees with which I am acquainted. The legislation creating the commission ought to require the concurrence of this commission in the programs submitted by the Office of Saline Water. Only in this

way can we guarantee into the future the technical excellence that this program requires.

I note in the program for advance desalting technology, there is mentioned a commission or a committee. This committee would have a different function. It may well be treated as I was. Namely, I was asked to consult and I gave advice and my name appeared as one who had helped in the preparation of the report for advance nuclear technology, but what would not be obvious to the casual reader is that most of the recommendations in that report are exactly opposite to what I recommended.

Senator JACKSON. May I interrupt there? With all due respect, in the 25 years I have been in Congress, one of the continuing problems that arise when you appoint an advisory commission is some individuals on a commission think they can come down three times a year and then leave a set of directives to the director and, if they are not carried out, he wants to leave.

Mr. TRIBUS. No. I have served on commissions, for example, advisory to the old NACA. Our function there was to hear the technical people tell their story and to have it argued out in front of the technical director. Major errors then do not creep through.

In other words, as one who has run technical programs and worked with advisory commissions, I know how the commissions should be used.

Senator JACKSON. I am glad to hear you say that, because I think it would be a tragedy if someone gets on an advisory commission thinking that they are going to be given approval on every recommendation that is made. It is easier to come forth with a whole set of ideas how a given operation should be handled when you are only here four times a year.

Mr. TRIBUS. I understand that, sir.

Senator JACKSON. This can be very trying on a good administrator and a competent one.

Mr. TRIBUS. It certainly can. On the other hand, it can also protect a good administrator from these kinds of pressures and these kinds of statements.

Senator JACKSON. If it is handled on a give-and-take basis and the person who is presenting a program cannot stand up against thorough cross-examination scientifically, then there is something wrong with it. That kind of exchange is good.

Mr. TRIBUS. This is what I have in mind.

Senator JACKSON. Fine; very good.

Mr. TRIBUS. Second, I propose that you make an appropriation which will carry the Federal Office of Saline Water for the next 2 years at a budget which is approximately 50 percent larger than the one they now have and that you set aside the present program.

This will give the new director a chance to continue the basic and engineering studies but not to build new demonstration plants. It will also give him a chance to submit a new program. I remind you that the program before us is not his. It was put together under his predecessor and does not represent a coherent and logical development program. It would be unwise to saddle him with such an ill-conceived approach as has been thus far given to us. We are much more likely to receive a proposal that makes good sense.

(c) Third, I urge you to take steps to assure that the economic studies called for in the legislation of 1961 are actually carried out.

Even as late as 1962, the then director of the program wrote me as follows:

Recognizing as you do the importance of economics to the problems of saline water conversion, the Office of Saline Water is establishing an economics group to undertake economic studies.

It is indeed disturbing to realize that OSW, as late as 1962, was just beginning to establish such a group. It should have been one of the first groups established in that Office.

The very final sentence of section VIII of the report "Program for Advancing Desalting Technology"—almost as though it were an afterthought—states:

In addition, an analysis will be made of each process to determine those components on which work should be concentrated.

I note, however, that such studies are not budgeted in the report.

It is a shocking admission that only now, after all these years, will the Federal program begin to use their money to make this sort of analysis in order to decide where to spend the taxpayer's money. I am confident that the new director of OSW is sensitive to these matters. But because the matter of properly directing our efforts is so critical, I urge you to consider in your wisdom, legislation which will, in fact, insure that this kind of work is actually carried out. In this connection, may I call your attention to a report by the TVA, technical report No. 31, which describes an economic analysis of the Johnsonville steam generating plant. In this report, for example, it will be found that there are cost breakdowns on every item of equipment, every labor cost, including a breakdown by hours of labor, categorized as to type. I am referring here not only to the estimated costs, but the final installed costs after the bids were acted upon. It is out of lessons such as this that engineers can decide how to improve their systems. I hope the director of OSW will gather similar data and I urge you to authorize a suitable budget for the purpose. In the absence of this sort of information, each construction job teaches a lesson only to the successful contractor. If he does not carry out his responsibilities, nobody learns. To build demonstration plants and not record the most important data available from these plants is a shameful waste of the taxpayer's money. Indeed, if there is no intention to gather this sort of information, then, in my mind, there is really no need to build these plants in the first place.

I found the statement of Philip E. Bush of Kaiser Engineers, given yesterday, extremely interesting because he talks of how the costs were driven down over the years. I would point out that this is the result of each year having engineers trying to meet the market price. They did not start out back in the early days by trying to get a factor of 10 or a factor of 100 on the plant. This would be equivalent to what the Russians did when they built the Do-X. It is very likely to take us in the wrong direction and not give us information that would be very relevant to where the water needs are.

In closing, I would also urge you to approve the request to establish and staff two research laboratories, one on each coast. These laboratories will have much work to do in the future.

The water problem will be with us for a long time to come and we must face the fact that we are in for a long tough job of constant cost reduction. I do not look for any great dramatic breakthroughs. Rather, I look for a decrease in the cost of water as we apply ourselves steadily and patiently to the reduction of every item of cost in connection with the various processes. In short, we shall reach our goal only by hard, patient, sensible work. Let's organize to do it. Thank you.

Senator ANDERSON. I would first of all call your attention to the paragraph just above the last one, where you would establish two research laboratories, one on each coast. I drafted a bill for these and I provided for the construction of a laboratory on the east coast and one on the west coast. The then majority leader did not move the bill very rapidly. I went to Mr. Johnson and asked why. He reminded me there were three coasts, one of them the gulf coast, and the first plant was built on the gulf coast.

You suggested at the top of page 8 that we make an appropriation to carry the Office along for the next few years on a budget approximately a half larger than what they now have. I imagine you took into consideration the fact that this present program, so-called, is within the President's budget.

The President has suggested expansion of the program.

Mr. TRIBUS. Yes, sir.

Senator ANDERSON. You would cut it back down?

Mr. TRIBUS. I would not expand it in the manner that was proposed in this report. His recommendation for the expansion, I believe, is based on the program for advancing desalination, the one of October. That report is the one that recommends approximately \$200 million increase and allocates how the money will be spent. I think the President was poorly advised in that report and I would like to see him get advised again.

Senator ANDERSON. You say you would set aside the present program?

Mr. TRIBUS. I would set aside the program in this report, "Program for Advancing Desalting Technology." I would let the director put together a program based on the kind of studies I have mentioned. I am confident that program will come out looking rather different from what is in this report. This is what I intended to convey by those words, sir.

Senator ANDERSON. You do not believe, then, in the construction of these plants and having them work out their own salvation by cutting costs down considerably.

Have you had any experience in building a land-based reactor in the western part of the country?

Mr. TRIBUS. No, sir.

Senator ANDERSON. Well, they built a plant at Shippingport. The cost at Shippingport is rather high, is it not?

Mr. TRIBUS. Nuclear energy is rather different.

Senator ANDERSON. Would you not have built the Shippingport plant?

Mr. TRIBUS. Yes.

Senator ANDERSON. Why? It has high cost?

Mr. TRIBUS. But atomic energy is a different sort of thing. We have a lot to learn there. Here we are playing with industrial processes, almost every one of which is well known.

Senator ANDERSON. You do not think we have a lot to learn in desalination?

Mr. TRIBUS. Yes, the question is, How to learn it?

Senator ANDERSON. You said we have a lot to learn in atomic energy?

Mr. TRIBUS. I certainly do think so.

Senator ANDERSON. A lot to learn in space?

Mr. TRIBUS. Yes.

Senator ANDERSON. A lot to learn in this program?

Mr. TRIBUS. It is a different thing in this program.

Senator JACKSON. Is it a lot to learn? As a lawyer, I get the feeling in our space problems and our desalination program, it involves proper use of materials; it involves, in short, the engineering disciplines.

Mr. TRIBUS. It certainly does.

Senator JACKSON. We know the basic concepts, but the engineering discipline is heavily, heavily involved. Now, do you not really learn by doing?

Mr. TRIBUS. You certainly do. It is a question of what you do and how you learn from it. In the case of going into space, for example, sir, we have never been out there very much. When we make a mistake, it is extremely difficult to rectify. When we build a sea water conversion plant, when we make a mistake, the problems of rectification are purely economic, not overly large. When we make a mistake in space, we blast 10 megabucks every time.

Senator JACKSON. I agree, but I thought all science involved trial and error.

Mr. TRIBUS. It certainly does, but this is a problem in engineering.

Senator JACKSON. Is not that expensive, trial and error?

Mr. TRIBUS. Yes.

Senator JACKSON. But is there not trial and error in engineering?

Mr. TRIBUS. Yes, there is trial and error, but all trials and errors do not teach you equally well.

Senator JACKSON. Well, if it did, we would know just how much we could waste.

Mr. TRIBUS. But we know in the case of reduction of the costs of items; we know a lot about how to do that as opposed to doing something which is technically very new.

Senator JACKSON. But can you predict, after you have a given concept, and it must be implemented by the engineers, you need to build a plant—

Mr. TRIBUS. Yes.

Senator JACKSON. Can you really predict accurately what the costs are going to be?

Mr. TRIBUS. No, and you do not learn by building a demonstration plant.

Senator JACKSON. Assuming you use the best possible people, isn't the last analysis that you are going to have to build a plant? Is it not possible you are going to find the best materials are not the right materials? Isn't this so in the space problem?

Mr. TRIBUS. Well, you have two parts to your question. One is, "Aren't we able to predict the costs?" The answer is we do not predict

them terribly accurately, but we do not miss by too much, either. We do this in the chemical industry very well.

Your second part is, "Do we not learn about materials?" You learn a lot about materials, but you do not have to build a great big plant to do that.

Senator JACKSON. When you test out your materials, the whole thing may not start operating, but it is very unlikely.

Mr. TRIBUS. This is very unlikely in actual practice. We run into difficulties but we work our way out with the plants. We ran into sea grass at Point Loma which we had not anticipated, but they worked their way out.

My point is you do not have to build large demonstration plants. We should find places where people really need water. The engineers should be doing basic studies with prototypes, then building plants where people need the water. We will learn from those as we go along. There is no point trying to make a quantum jump today in our capacity unless we find somebody that really needs that water and they can pay for it at the best possible costs we can predict.

Senator JACKSON. Your main point is there ought to be small plants?

Mr. TRIBUS. If the city of Los Angeles, the Metropolitan Water District, indicates they want to build a 150-million-gallon-a-day plant, and they say it is necessary to do it now, I think it would be fine for the Federal Government to help them do it because it would be good to get the experience. But I would not build a plant of, say, 50 million gallons a day where people do not need the water.

Senator JACKSON. If you build it in California, you will always find a need?

Mr. TRIBUS. Not at the cost. When you get right down to it and ask the people, "Are you willing to pay for it?" they often find, if the cost is too high, they can do without it. When you get down to it, the people in California could be using the water from the Hyperion sewage plant. They can get a lot of water and it will be a lot cheaper to clean up and use than the desalinated water.

Senator ANDERSON. Is that the storm sewer?

Mr. TRIBUS. Yes, sir. It does seem a little silly to take water that is almost fit to drink and dump it into the ocean and then go up the coast and get the same water and put it through a desalination process.

Senator ANDERSON. The people in cities ought to have a say about what they want to do. If the cost is 30 cents, is that too high for industrial purposes?

Mr. TRIBUS. No, unless they can get it cheaper in other ways.

Senator ANDERSON. What you are saying is there is not enough to be learned in these large demonstration plants?

Mr. TRIBUS. To justify the cost. There is a lot to be learned, but we are going to learn it along the way.

Senator JACKSON. You feel you can learn just as much in the smaller ones on the basis of costs rather than build the bigger ones?

Mr. TRIBUS. In particular, as we design for the market price, we learn the things to emphasize.

In the 1930's, the British decided to play this game, too. They let two contracts for the R-100 and R-101 dirigibles. This has been

recorded in a very nice biographical book by Neville Shute under the heading "Slide Rule"—the fellow who wrote "On the Beach." He described what happened when these people started to build a dirigible for the transatlantic crossing so Britain could get in the race. All the things they did turned out to be irrelevant, because they were building a demonstration, not trying to meet a market.

Senator JACKSON. Is that not comparing apples and oranges? If you start out on a false premise you are apt to end up with a false conclusion. I do not think you can compare a dirigible with what you are talking about here.

Mr. TRIBUS. I am comparing the engineering and here I think it is pretty much the same. If you take a group to build something and you do not have a market for them and make them face the possibility that if they do not do the job right, they are out of business; if you do not have this kind of framework, money goes in all directions on things that do not matter and the cost of the plant goes up.

Senator ANDERSON. What would it be in the construction of nuclear plants for power if we built only in accordance with the market?

Mr. TRIBUS. I said in the case of nuclear power we were playing with things where we did not have a wealth of background, as we do in evaporation and condensing processes. If we were playing in water as we were there in a very new technology, it certainly was worth while. I spent a lot of time myself on the design of the nuclear airplane. Obviously, this thing has no commercial value, but there was a point where it was worth going ahead because nobody had done this thing before. It was worth spending the money to explore. But in evaporation and distillation, we are just not in that kind of game. We know a lot about this.

Senator ANDERSON. One other thing I want to ask a question on, page 8, where you want to set up a new commission, you say the legislation creating the Commission ought to require the concurrence of this Commission in programs submitted by the Office of Saline Water. Should we take it out of the control of the President and the Congress and the Commission and put it in the hands of the Director?

Mr. TRIBUS. I would defer to your judgment on the proper way to operate the Government, sir. The point I was trying to make was—

Senator ANDERSON. This is the way the Government operates. You want to stop it. Why?

Mr. TRIBUS. I would defer to your judgment as to the powers of this Commission. My objective in this recommendation—

Senator ANDERSON. If you apply this all the way through, you would abolish the Congress; would you not?

Mr. TRIBUS. Oh, I certainly would not.

Senator ANDERSON. If all these programs are not going to go through the Congress, but through some commission—

Mr. TRIBUS. I think there is a difference between presenting technical information to a Congress made up largely of people not technically qualified—they are excellently qualified in many ways, but they can be fooled by people who make incorrect statements.

Senator ANDERSON. Can they get lectured for their ability to fool us?

Mr. TRIBUS. Nobody questioned their ability to pass examinations in thermodynamics, sir.

Senator JACKSON. We may have technical problems before us, but we have to exercise judgment and those of us who have been wrestling with some of these highly technical problems in the long run take a look at the people who come and testify and have respect for one person's judgment over another, which is proven by accomplishment and so on. We can render, I think, judgments even though the problems presented are rather technical.

Mr. TRIBUS. I think you do remarkably well, sir, but the problem is, as I read the record, that many things are said which would not be said in front of you if you were, say, registered engineers.

Senator JACKSON. Why should they not be said if they want to say them?

Mr. TRIBUS. But you should challenge them. If qualified people were present, those people would make some misstatements that have been made here and you would say, "Well, wait a minute; that is not so." The witness would back away and understand that they could not come before the Congress and make such statements. This is what I am after.

I served as adviser to the Elliot committee. Here I came away with the strong impression that what the Congress needs is its own set of technical advisers. I think every Congressman ought to have someone he can turn to, every Senator ought to have someone he can turn to that he can say, "Look, here is a technical report; is this really solid, is it so?" He could ask questions and we would not see coming before the Congress people who would make statements such as I have heard.

Senator ANDERSON. Our position might be a little different in the atomic energy field, for example, where I have spent some time and so has Senator Jackson. We had Jim Ramey for many years. We did not pass on these things. We would say to Jim, "You bring us back some answers." He would consult with some people, sometimes experts we did not know existed; we got answers.

If you are going to suggest that the commission setup here is going to have to concur in the programs submitted by the Office of Saline Water, I think it is going to be like what Wilson said, that a board is long and thick and wooden.

Mr. TRIBUS. Yes.

Senator JACKSON. May I ask you, have you ever heard of such a commission being set up in the Government? We have a lot of distinguished advisory commissions today, starting with the President's own Science Advisory Committee. Have you ever heard of such a thing?

Mr. TRIBUS. I would be very happy to withdraw that particular sentence which calls for the concurrence of this Commission in programs submitted by the Office of Saline Water, but I do not want to see a commission which can be used as a sort of front and which is not heard when the chips are down.

Senator JACKSON. I think a commission is a fine thing as long as it remains an advisory commission. I take it that is what you have in mind.

Senator ANDERSON. Thank you for your very interesting presentation.

Mr. Godwin?

STATEMENT OF R. P. GODWIN, MANAGER, SCIENTIFIC DEVELOPMENT DEPARTMENT, BECHTEL CORP.

Mr. GODWIN. I am R. P. Godwin, manager of the Scientific Development Department of the Bechtel Corp., San Francisco. I am responsible for development and advanced engineering within the company in new fields of potential interest.

As a mechanical engineer I began my professional career in equipment design and metallurgical development in the machine tool and aircraft engine field. In 1950, I joined the Atomic Energy Commission as a reactor engineer at its Hanford, Wash., facilities. Later I was Assistant Director of Reactor Development for the AEC in Washington and concurrently Chief of the Office of Research and Development of the Maritime Administration. In 1961, I joined the Bechtel Corp., where I have been responsible for development and engineering in the nuclear and saline water fields.

The activities of the Bechtel Corp. are primarily in the engineering, construction, and construction management fields. Our major activities include powerplants—nuclear and fossil fueled; hydroelectric plants and water resources development; chemical, petrochemical, and refining processes; oil and gas pipelines; power transmission; metallurgical plants; food processing; and a variety of types of manufacturing plants. While our headquarters are in San Francisco, our work is truly worldwide.

Bechtel has provided desalting facilities in connection with a number of projects both in the United States and abroad over a number of years. These have included water supplies for pipelines and refinery projects, chemical plants, major powerplants, including the San Onofre Nuclear Generating Station now under construction for Southern California Edison, which will have a desalting facility of about 200,000 gallons per day capacity.

There appears to be little doubt that with large demands for fresh water from agriculture, industrial, and domestic sources that major steps must be taken now to prevent severe shortages. It is therefore quite natural to turn to the oceans for unlimited supplies of water—contaminated as they may be with salt. Sea water, however, is not a practical source of water for inland use, and they need not be, as vast quantities of water are available in brackish subsurface reservoirs and in polluted streams.

We also believe a prudent course to follow in meeting future fresh water needs is to seek economic means to reclaim irrigation runoff and urban sewage. These sources, blended with existing fresh water supplies and desalted sea water, should provide flexibility and further cost advantages.

The scale of water reclamation in the future will be large by any standard, thus new approaches are mandatory if we are to reduce cost of water to come within reach of the farmer. Essentially all of the desalting facilities which we have designed and built to date have been of modest size and have primarily involved the specification and installation of equipment supplied by manufacturers.

Some 5 years ago we recognized that another phase in the evolution of desalination was approaching and devoted our efforts to acquainting ourselves with the state of development, the prospects for improve-

ment, and to evaluating the potential of desalting on a large scale. One of our major conclusions was that nuclear heat sources were likely to prove advantageous for large desalting plants when coupled with power generation.

At the same time we recognized that considerable development and engineering application work remained to be done, even for the best known processes. Since the subject of this hearing, bill S. 24, relates to the expansion and acceleration of this program, I would like to review some of our work and comment on the significance of it with respect to requirements for future development.

In 1962 Bechtel studied the actual cost experience of the then operating demonstration plants for the Office of Saline Water. These were the Freeport, Tex., long-tube, vertical multiple-effect evaporation plant, the Webster, S. Dak., electrodialysis plant, and the San Diego, Calif., multistage flash evaporation plant. Our results showed that when compared on the same basis and without the experimental features, the cost of water from the San Diego plant was \$1.30 per thousand gallons and from the Freeport plant the cost was \$1.46 per thousand gallons in the 1-million-gallon-per-day plant capacity range. A comparable cost of water for the Webster plant, but operating with its brackish water feed, was \$1.15 per thousand gallons in the 1-million-gallon-per-day size range. When the MSF and LTV plants were compared at 8 million gallons per day, the costs of water were 73 cents and 85 cents per thousand gallons. From these results, it was evident that the multistage flash process showed promise of significant cost reductions in larger sizes. It is noted that it is now the process being most intensively investigated in large plant sizes for sea water conversion. These results also showed the superiority of electrodialysis over the multistage flash when brackish waters of moderate salinity are encountered, and where the water demand is small.

Following this work, Bechtel Corp. performed a conceptual design study of very large multistage flash desalination plants for the Office of Saline Water. We prepared designs of 50- and 150-million-gallon-per-day plants, estimated their costs, and determined the cost of water from single-purpose water plants, and dual-purpose plants producing both power and water. The results of this study have been widely used. They were the basis of the water conversion costs reported in the Office of Science and Technology's landmark report on the potential of nuclear energy for desalination.

One result of this study was that combination desalting and power-plants were advantageous, at least under the conditions assumed in the study, in reducing the total costs of power and water. It was evident that further work needed to be done to investigate the characteristics of such possible combined operations on actual systems as compared with the idealized conditions postulated in the study.

Another important result was to show that large-size plants could desalt sea water at costs which might be acceptable for large-scale use, costs of the order of 35 to 40 cents per 1,000 gallons.

During this study we developed a computer program which was used to determine the optimum plant design to produce water at the lowest cost. This computer program and variations of it are now widely used for conceptual designs of flash evaporation plants. The Office of

Saline Water recently requested that we provide copies of our program to nearly 20 of their contractors, who are engaged in conceptual studies of plants of 50-million-gallon-per-day size.

Also in this study, we recommended that concrete was potentially an economic material for evaporator vessels and we are pleased to see that the Office of Saline Water is now carrying out a program to develop and test concrete vessels.

The use of concrete for evaporator vessels looked sufficiently promising that we undertook in-house a study comparing concrete with steel to determine the savings which could be made in small and medium size plants. We found that plants as small as 1 million gallons per day could be built cheaper with concrete because it is ideally suited for on-site construction and costs are reduced by casting repetitive modules. Such construction may be of particular importance abroad.

Our study brought out several questions which must be answered before concrete can be used. What are the most suitable coatings to render concrete practically airtight to prevent leakage through the vessels? How can construction joints and seals be made to provide a leak-tight structure? At what temperatures must the vessel be lined to prevent attack and what materials should be used?

We hope the present OSW tests designed to answer these questions will show how concrete can be used in sea water conversion evaporators.

Recognizing the inherent potential merit of large-size nuclear power reactor plants as a source of inexpensive thermal energy for desalination plants, the U.S. Atomic Energy Commission in 1963 awarded a contract to Bechtel to assemble cost data for reactor powerplants ranging in size from 1,500 to 25,000 megawatt thermal.

The types of reactors included light water moderated and cooled; heavy water moderated, organic cooled; graphite moderated, light water cooled; and fast breeder reactors. Designs representative of both current technology and advanced concepts were included. The AEC Division of Reactor Development, and the AEC Hanford, Savannah River, and Oak Ridge Operations Offices or their subcontractors all supplied cost information for this study.

The results of this work should furnish guidance for reactor development planning. Of immediate application, however, the results formed the basis for the estimation of the steam costs for the Office of Science and Technology's Interagency Task Group assessment of large nuclear powered desalination plants.

I would also like to mention briefly another important project we are presently doing even though it is too early to report any results. This is the desalting plant study for the Metropolitan Water District of Southern California which is partially supported by the Office of Saline Water and the Atomic Energy Commission.

The objective of the project is to determine the engineering and economic feasibility and provide a preliminary design of a combination power and desalting plant using a nuclear energy source. This combination plant shall be suitable for operation by the district by the year 1970. The study includes an analysis of combination plants with outputs of 50 to 150 million gallons of water per day and 150,000 to 750,000 kilowatts of electric power.

We believe the results of this study will make a significant contribution by determining, on a realistic engineering basis, the immediate prospects of desalted water as an added source of water supply for southern California. This study will furnish an opportunity to examine in detail the important practical aspects of combined operation, water storage, transmission and blending, and other aspects of a large actual system.

I would now like to comment on areas of general research and development in desalting technology wherein we feel that useful results obtained could make further advances in the art possible.

In the evaporation processes, it is probably accurate to speculate that favorable results in research and development would probably provide percentage reductions in cost of desalinated water but probably not reduce cost by a large factor. Areas needing work include (1) better definition of design parameters for orifice and baffle configuration, (2) better utilization of pressure differences, (3) better and less expensive condenser tubing materials, (4) improved pumps, (5) low-cost scale prevention and deaeration techniques for cool sea water.

For the single-purpose water-only evaporation plants where high temperature operation with associated gains in thermal efficiency may be desirable, we need cheaper heating sources, improvements in process design, improved materials for the higher temperatures, and low-cost scale prevention techniques.

With regard to the nonevaporative processes and considering fruitful areas for development, it is noted as previously pointed out, that the electrodialysis process is generally preferred today in the brackish water areas for municipal water desalting. Reverse osmosis is still promising but we need to reduce costs and improve membrane lifetimes.

It is our conviction that more attention should be devoted to ascertaining the requirements for water desalting—market surveys, if you will. Further, such work is needed to clarify the potential demand for water desalting facilities in the various size ranges and thus the emphasis in the development program. Those who have attempted such surveys will agree that this is a complex and difficult task due to the many factors involved. Nevertheless, it seems essential.

It should be remarked that there are few areas where the costs have as little relationship to the price as in the case of water supplies. This is particularly frustrating to engineers who are accustomed to a close cost-price relationship. There are many reasons for this situation, most of them quite valid. However, the problem in trying to evaluate the potential of a new technology in such a situation on the basis of cost is not an easy one.

It must be noted also that there is a considerable tendency to consider average prices and costs when the incremental costs of adding to or even replacing existing water supply systems may be much higher than reflected in averages.

In short, the question of ascertaining the potential demand for desalted water as a function of price and quantity must be approached with a great deal of good sense and understanding of the many practical circumstances involved.

While the foregoing has necessarily been rather general, I believe it supports our conviction that additional development work as well

as more research is needed in the field of saline water conversion, and that we are thus in support of the objectives of S. 24, a bill to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

This completes my statement and I would be happy to answer any questions.

Senator ANDERSON. Thank you very much for your statement. I am particularly happy that you see some value in building these plants. Even though they are not the last word in engineering and not the last word in cost development, you see some possible developments emanating from them.

I see you say attention should be devoted to ascertaining the requirements—what is the market, in other words. I think that is a very useful suggestion and ought to be followed.

Senator JACKSON?

Senator JACKSON. You have mentioned that you were hired by the Office of Saline Water to do a cost analysis of the various types of plants. How thorough was this? I ask this because the previous witness raised some questions that should be responded to. I would like to get your evaluation of the cost analysis made by the Bechtel Co.

Mr. GODWIN. Well, the study that was done at that time I think was in sufficient detail that we could, at the conclusion of the study, essentially guarantee the price of the construction of the plant.

Senator JACKSON. Was it costed out in detail?

Mr. GODWIN. Well, let me say this: What we did was to analyze the operating experience with the then operating demonstration plants. We then eliminated what would be termed developmental features; in other words, we took out a lot of equipment which was there just to get readings and data. We normalized the plant to standard site criteria. What we did was to compare them on a comparable basis, such that we analyzed each of the primary components of the plant, cost estimates, and we feel there was a sound economic evaluation made.

Senator JACKSON. Let me put it this way: Suppose you were bidding on a given job. Would you have relied on the cost analysis that you made to submit a bid involving a similar project if called upon to submit a firm proposal?

Mr. GODWIN. I think the answer is "Yes." We went as far as we normally would to submit a bid.

Senator ANDERSON. Is not a plant being built by Southern California Edison that you made a very careful study for?

Mr. GODWIN. No, there are similar plants being built of a multi-stage flash type, like the Point Loma plant. But our studies were provided to better understand the relative merits of each of the processes being used at that time.

Senator ANDERSON. I do not find it here but I understood a plant was being built in California on which Bechtel did a lot of work.

Mr. GODWIN. I mentioned the one which was being built in connection with the Southern California Edison nuclear powerplant. But this was for boiler feed water essentially, makeup water, I should say.

Senator ANDERSON. Thank you, very much.

Mr. Ennis?

STATEMENT OF CHARLES E. ENNIS, ASSISTANT TO THE EXECUTIVE VICE PRESIDENT, CATALYTIC CONSTRUCTION CO., PHILADELPHIA, PA.

Mr. ENNIS. I am Charles Ennis, assistant to the executive vice president of Catalytic Construction Co., Philadelphia, coordinator of our company's activities in water conversion and project manager for Catalytic studies on the joint United States-Israel plant.

As a beginning, I should like to express appreciation on behalf of both Catalytic Construction Co. and myself for the opportunity of appearing before you gentleman to present our views on the present and projected state of the technology of desalination. Catalytic, as a major engineer-constructor, has a demonstrated interest and indeed a stake in desalting, both from the point of view of early company-sponsored engineering development programs and, more recently, in actual plant designs and economic-engineering studies. We are convinced that desalting is a science as opposed to an art, and indeed that it is a science reduced at this time to technology.

Mr. Philip Sporn, a recognized authority in power generation who is now intimately associated with various desalting projects, remarked during a recent presentation in New York that "We are as sure of the principles involved in desalting as we are of the multiplication tables." On this premise, then, it is our contention that the basic physical and chemical mechanisms of the distillation processes involved in desalting are predictable, controllable, and well understood. If this premise is accepted, it becomes evident that we are at a point in the reduction of principles to practice where it is necessary that we leave the research scale process and the pilot plant and proceed to a product-type plant of a sufficient scale to insure that the economic relationships exist in their true balance. By this I mean a plant producing sufficient product to guarantee that we do not have an inflated effect of capital cost over operating cost, general cost over maintenance charges or indeed any distortion of the effect of economic parameters.

By the foregoing, I do not imply that today the distillation process, as an example, stands completely refined, fully developed, and available in its ultimate form. What I do say is that we have reached a point in the engineering and economic development of desalting by distillation where to make further significant progress it is necessary that we leave the pilot plant and go to the production plant. The basic process is proven; what remains now to be proven is the economic attractiveness of the process.

You may well ask what can be learned in a production scale plant that cannot be learned in a pilot plant—or at least a demonstration plant. If I may be allowed to relate the desalting of water to any other chemical process, I think I can draw some parallels which will be of interest. To quote from an article on ammonia plant costs in the February 3, 1964, issue of the Oil and Gas Journal:

In the last 10 years, investment for ammonia plants has been decreased by about 25 percent on a dollar-ton basis.

The decrease in ammonia plant cost has come about in spite of an increase in overall construction costs. Over the same period the Engineering News Record index for construction costs shows a total increase of about 50 percent.

These cost improvements resulted from a number of factors, not the least of which was improvement in technology in the interim period. However, other significant savings were effected through improved design approaches, better use of available materials and a definite improvement in productivity both in design and construction phases brought about by what is usually termed the "learning curve."

This learning curve concept is no illusory thing. The U.S. Air Force, among others, makes use of the learning curve in contract negotiations, particularly on repetitive work to insure that they reap the benefits of improved productivity. I might cite as specific examples some recent missile installation and modification projects performed by Catalytic. The nature of the work involved, while not directly related to the type of work involved in the construction of desalting plants, is analogous to desalting plant work in that it is highly repetitive. In the case of specific tasks on each of these projects, the improvement in time required for accomplishment and dollar costs is observed and is plotted as backup for cost negotiations. I would make the point that we might expect a similar improvement in the construction of a production scale desalination plant with the repetitive operations involved in construction of stage bodies, evaporator bundles, pump installations, and so forth.

To return to the specific area of desalting technology, it is apparent that work done to date and principally funded by Office of Saline Water has made it possible to be much more specific in our approach to reduction in cost of product water. In this respect, I would cite the study performed by Catalytic, with Nuclear Utility Services as a sub-contract entitled "A Study of Desalting Plans (15 to 150 million gallons per day) and Nuclear Powerplants (200 to 1,500 megawatts thermal) for Combined Water and Power Production." This study, performed for the Office of Saline Water and the U.S. Atomic Energy Commission, examined in some detail the interrelationship of the various cost elements involved in production of water. Thus, the results of this study permit the direction of future effort to those areas of plant concept, design, and operation which show the most promise of large unit cost reduction per unit of developmental effort expended. Briefly stated, this study indicated that in the distillation type—and specifically multistage flash distillation type—process plants the major cost determinants were external economic factors rather than internal or process-related economic factors. From this we may draw two inferences:

1. The rate of savings improvement in product water cost would be less from further laboratory scale work on the presently conceived processes than from basic improvements in concept or approach in funding or method of costing energy supplied the plant, and

2. That a production scale plant built today would be fully capable of taking advantage of cost savings made through the latter two courses of approach even though these savings might be made after the plant was constructed and on line.

Still another area of cost improvement lies in the possibility of cost reductions in equipment items which might be achieved only if a relatively large market exists for these equipment items. A large part of the equipment cost in a multistage flash distillation plant is in evaporator surface and pumping equipment. Considering these sepa-

rately, it has been said that a 150-million-gallons-per-day plant would require approximately 10,000 miles of evaporator tubing. This is, by an order of magnitude, more tubing in a single order than even the largest tubing manufacturing company's standard costing procedures envision. To effect full advantage of such a bulk order, it is, from a practical point of view, necessary to actually place such an order. In realistic terms, there is today no incentive for a producer of this material to develop the product availability or even to do the detailed costing exercises in order to get an accurate fix on the cost of tubing in this volume. In considering the pumps involved, we have no doubt that their design and fabrication is within the limits of current technology and capability. However, there is no production experience on such equipment in the size range we are considering and there is no cost experience. The presently active grants from Office of Saline Water to various pump manufacturers to develop designs and estimating information perform a useful and vital function. However, again we will never know the cost of one of these pumps delivered to a site ready for use until we actually place an order and see the pumps built and in service.

In very broad and general terms, to consider the current state of multistage flash distillation, I would say that we could predict within plus or minus 10 percent the cost of water from a 150-million-gallon-per-day plant. Notice I say, "cost of water." You have all read in the public press releases from various agencies and organizations wherein predictions are made of water "costing" anywhere from \$1.25 per thousand gallons to \$0.05 per thousand gallons. We can produce water today in existing plants at a cost approximating \$1.25. I feel certain that we will never produce water by the multistage flash process at a cost of \$0.05 per thousand gallons. We may be able to sell water from such a plant at a cost approaching this by dint of some rather obvious accounting exercises, but the fixed charges on capital investment alone would preclude water production at cost levels this low. The point I would make here is that we feel that major cost improvements achievable through process research and development with the current process concepts have largely been made. Using current process concepts, cost improvements can and will be made through the effect of a construction learning curve, through improvements in unit equipment costs felt to be reasonably anticipated in large orders actually in hand by the manufacturers, and through the benefits expected in operational unit cost reductions in larger plants.

The foregoing, then, presents our views as to the current situation with respect to efforts to reduce the cost of desalting brackish and sea waters. A point of more immediate interest to you gentlemen, however, lies perhaps in our concept of the areas of activity of the Government and of private industry in this overall program. I stated earlier that in our opinion the major process related cost improvements in current technology have already been fairly completely exploited in the case of the distillation systems. However, an area in which great promise of significant reduction in product water cost lies is in improvement in basic process and plant concept. It is, in our opinion, possible to effect appreciable savings in product water cost by a re-study of the basic components of the dual-purpose water desalting-power generation plant. However, such a unique approach to the

dual-purpose plant concept as envisioned here would require governmental direction for two principal reasons: (1) In all probability present power and water utility regulatory policy would have to be modified to permit the type of plant concept which would yield maximum benefit in terms of cost savings; (2) an approach as unique as that foreseen would, by virtue of its lack of precedent, undoubtedly encounter difficulties in funding from private sources. For these reasons, Government sponsorship of some type is seen as a necessity to maintain the program's momentum.

Another major consideration affecting the timing of assumption of major responsibility for the desalting program by private agencies is the degree of confidence existing in the technology of desalting. To explain this statement I believe it is necessary to consider the present status of the Government effort in desalting. The Office of Saline Water is recognized worldwide as the leader in the development of desalting technology. Therefore the course taken by Office of Saline Water will profoundly influence the course of private participation in desalting projects. If the Office of Saline Water continues to operate solely on a laboratory, pilot plant, and even demonstration plant scale, then private agencies will confine their activities to these levels. Conversely, if the Office of Saline Water adopts an aggressive stance in the promotion of a production scale plant, its lead will be followed by a broad spectrum of private industrial and local governmental units. Office of Saline Water has led the desalting program through process development and confirmation. It now remains for it to maintain this leadership through the intermediate and large-scale plant programs necessary to the economic confirmation of desalting technology.

For as long as Office of Saline Water indicates a confidence in desalting private agencies will support and follow its lead. On the other hand, for as long as Office of Saline Water refrains from moving into the large-scale plant portion of a desalting effort, private industry will temporize.

I thank you for this opportunity of appearing before your committee and assure you that we, at Catalytic, sincerely believe in the future of desalting as a practical solution to many of the world's water needs and are eager to continue our participation in this program.

Senator ANDERSON. I appreciate very much your statement, particularly this last portion, in which you point out that the Office of Saline Water must take the lead. I think it is a very excellent statement. You say that if the Office of Saline Water continues to operate solely on a laboratory, pilot plant, and even demonstration plant scale, then private agencies will confine their activities to these levels. I am glad you brought that out.

On page 6, you talk about the costs of water, and you said you feel certain that we will never produce water by a multistage flash process at a cost of 5 cents per thousand gallons. You do not think that the necessity of providing irrigation water is compelling in this, do you? If we were able to produce decent industrial supplies, that is enough for the present, is it not?

Mr. ENNIS. For the present. I think again desalting is one part of an integrated water supply program. Where the economics justify it, it is the way to go, obviously.

Senator ANDERSON. I would not want somebody to say that a desalting process is no good because it does not provide irrigation water for farmers. One witness said he did not think the price would ever get down low enough to be economical for irrigation water for farmers. Maybe he is wrong, maybe he is right. But we should have an economical cost for industrial water.

Mr. ENNIS. Certainly. I think I agree with what Dr. Hammond said this morning, that as an ultimate goal, I would not say that 5 cents a thousand gallons of water is not achievable. I would say a multistage flash plan is achievable.

Senator ANDERSON. I think he believes there are great possibilities in the future. I had better put it that way. I am glad that he does and I am glad that you do.

Professor Dusbabek?

**STATEMENT OF PROF. MARK R. DUSBABEK, REPRESENTING THE
FLUOR CORP., LTD.; ACCOMPANIED BY L. K. OLSON**

Mr. DUSBABEK. I believe that everyone here has a copy of my paper. With your permission, I shall just summarize it.

Senator ANDERSON. Thank you, that is very kind of you. We will put the statement in full in the record and you may summarize. I appreciate your desire to cut it down.

Mr. DUSBABEK. My name is Mark Dusbabek and I am speaking in behalf of the Fluor Corp. I have with me Mr. L. K. Olson, who is also associated with this corporation.

In preparing this paper, I had two or three main points I want to get across and I summarize these as a conclusion at the end of the paper. What I have attempted to show is the current status of the sea water plants, notably the multistage flash distillation process. It is our opinion that a process like this is well enough understood to be amenable to a fixed price, guaranteed performance type bid. On that basis, I constructed a cost estimate which indicated that a plant of about 150 million gallons a day, assuming steam from a nuclear powerplant, would result in water costing approximately 35 cents per thousand gallons. To support that position, I described the basic process and how fundamentally it is rather simple.

I also pointed out, however, that because it does involve fundamentals, these process steps have not been particularly studied. There are studies in greater detail in other processes, or other uses of these processes, because they were not the cost-determining factor. The plant that one would build today on the basis of these economics would not be the cheapest plant by any means. There are ways of achieving a cheaper plant by pilot planting and doing this fundamental research work on some of these phenomena.

Second, I pointed out that it is our opinion that a sea water conversion plant is enough like other chemical process plants to expect that as more plants are built and as these plants get larger, one will see a steady and almost constant reduction in plant costs and unit water costs.

The last point I wanted to make there was that because of the basic simplicity of the distilling process, however, we did not expect the cost reduction due to these two factors, with larger and more plants, to be as dramatic, perhaps, as was experienced with the ammonia industry.

I think that summarizes what I have to say, sir.

(The prepared statement referred to follows:)

STATEMENT OF MARK R. DUSBABEK, REPRESENTING THE FLUOR CORP., LTD.

My name is Mark R. Dusbabek and I am speaking on behalf of the Fluor Corp., Ltd. I have been employed by the Fluor Corp. since 1953, and during that time, I have been directly associated with all of Fluor's sea water conversion and nuclear activities. These activities included the first study performed under the auspices of the Department of the Interior of the applicability of nuclear energy to sea water distillation. That report, completed in 1957, was followed by many others for various clients. In all, Fluor has completed 21 assignments relating to 9 different sea water conversion processes, designed what is still the world's largest combination power and desalting plant, and was responsible for the design of the highly successful Point Loma plant which was subsequently moved to Guantanamo.

The Fluor Corp. is an engineer-constructor serving primarily the petroleum, chemical, and power industries throughout the free world. Our current billings, in excess of \$200 million per year, make us one of the world's largest engineering-construction firms. For the past 35 years, Fluor has been engaged in the design and construction of plants which utilize the basic operations found in sea water distillation plants. The great majority of that work has been done on the basis of a fixed price with guaranteed plant capacity, performance, and product purity. It is because of this experience that we feel competent to discuss the technical and economic status of desalting plants. Furthermore, we feel an obligation to provide this committee with whatever pertinent information we may have in order that their judgments will be as informed as possible.

Our studies have shown that distillation is presently the cheapest method of producing large quantities of fresh water from the sea. There are, of course, several variations of distillation processes from which one may choose; but, in general, all depend upon the heating, cooling, boiling, and condensing of water phenomena which have been studied extensively and are now well understood. If there are other processes which will produce cheaper water and which can be priced as definitively as the distillation process, then so much better. We will refer here only to distillation plants which are sufficiently developed to permit an accurate estimate of cost and performance.

In order to give credence to the following economic data, it is important that the basic elements involved in a distillation plant be understood. To that end we have shown three sketches which illustrate the essential processes. In figure 1 a source of heat is used to generate steam by boiling salt water. All of the salt stays in the boiling salt water while the steam is forced out of the kettle. If the steam impinges on a cold surface, as shown, it will condense into pure water. All that's needed to produce a pound of fresh water from a pound of steam, then, is a source of steam (boiling sea water) and a cold surface upon which to condense it.

Of course, when the steam condenses, it gives up heat. Figure 2 shows a way to get more than a pound of water from a pound of steam. Here the heat given up by the condensing steam is used to generate more steam from another pot of salt water at a slightly lower temperature. This procedure can be repeated many times and modern distillation plants could produce as much as 20 pounds of water for each pound of steam generated by the heat source. In order to make a commercial plant, means must be provided for pumping the salt water into and through the plant as well as collecting and removing the product water. But the basic processes involved in any distillation plant are as shown in figures 1 and 2. The simplicity should be obvious. Not only is the process simple, but the necessary equipment is comparable in design, materials of construction, and size with components now being routinely manufactured.

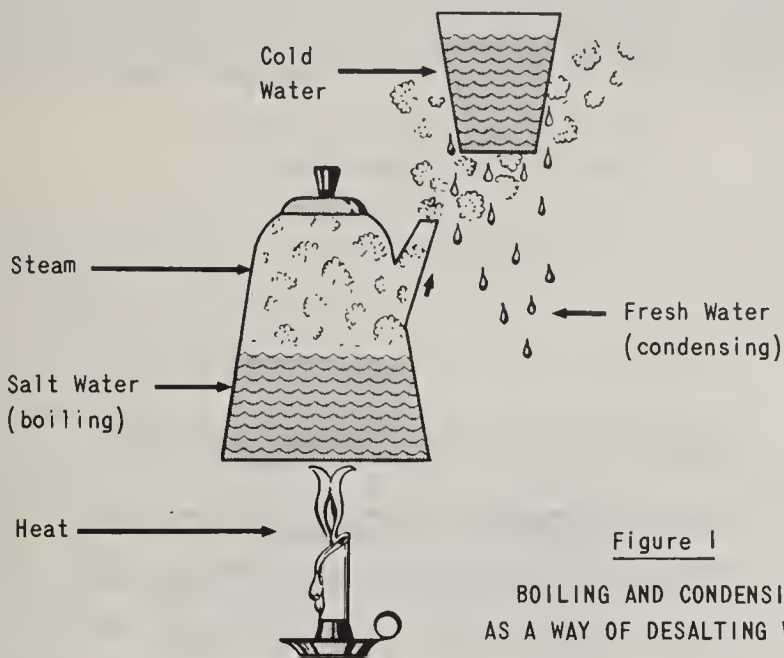


Figure 1

BOILING AND CONDENSING
AS A WAY OF DESALTING WATER

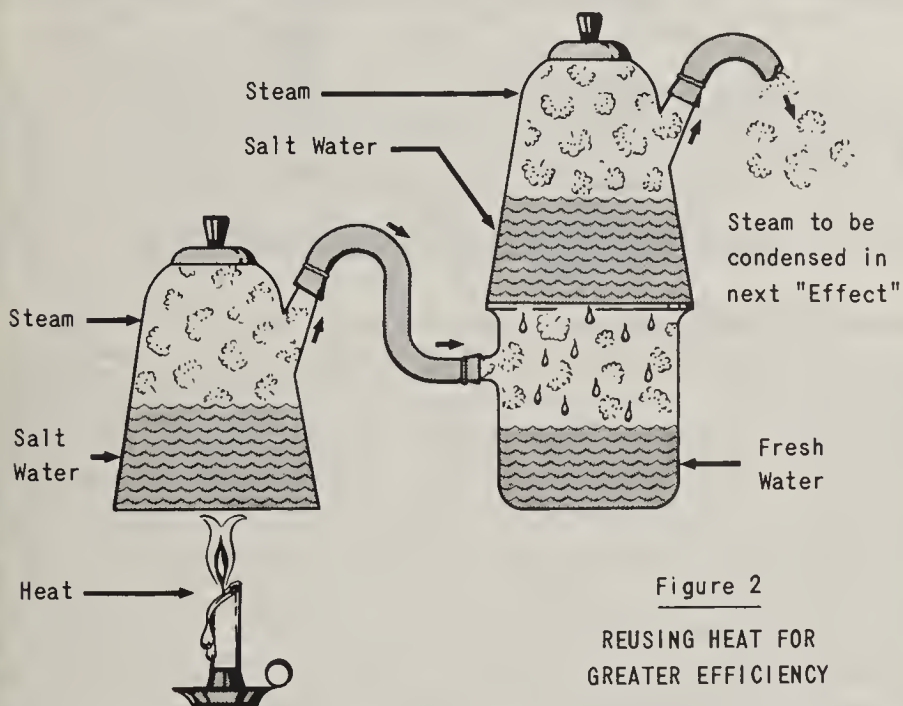


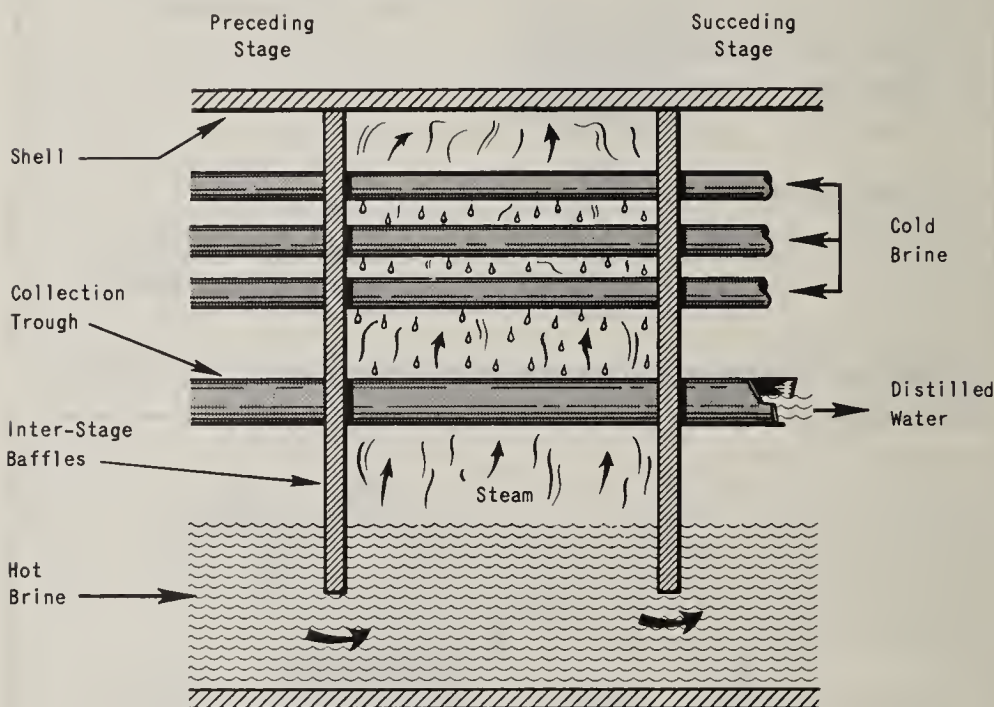
Figure 2

REUSING HEAT FOR
GREATER EFFICIENCY

For example, figure 3 shows the general arrangement of the equipment found in a typical stage of a multistage distillation plant. Here, the hot brine from a preceding stage is forced under pressure into a succeeding stage which is at a lower pressure. At this lower temperature, some of the water in the brine evaporates and is condensed on the tubes above. The tubes carry cold brine to the preceding stage where a similar process takes place at a higher temperature and pressure.

Figure 3

TYPICAL STAGE IN MULTISTAGE FLASH
DISTILLATION PLANT



The entire assembly resembles a large shell and tube condenser—similar to those used in steam powerplants. Single condensers capable of condensing 10 million gallons per day of water are now being installed in several powerplants in the United States. If 20 of these were connected in series, the resulting plant would resemble a sea water conversion plant with a capacity of about 200 million gallons per day—using essentially standard components. The pumps, associated piping, and sea water intake facilities being similar to powerplant equipment, are all standard and amenable to accurate predictions of cost and performance.

Because of Fluor experience with the design and construction of similar process plants, the basic simplicity of the process, and the commonplace nature of the required equipment; Fluor is prepared today to design and build a large multistage flash desalination plant for a fixed price with guaranteed capacity, performance, and product purity. It must be emphasized that the cost of water produced by a plant procured today under a fixed-price contract would be far higher than that produced by succeeding generations of similar plants. This is so because the waterplant price must include contingencies to cover uncertainties which now exist in the design data. Our purpose in presenting at this time an estimate of the cost of water from a large distillation plant is to provide a definitive benchmark against which we can compare past and future progress in this field. It is often argued for example, that it is impossible to predict with

any certainty what the cost of water will be from a plant many times larger than any built in the past. True, it is impossible to predict precisely what the water cost will be, but it is equally true that one can predict with certainty an upper limit which the water cost will not exceed. That is the kind of estimated water cost shown in table 1. Those items which could be made subject to guarantee are followed by an asterisk.

TABLE I.—*Estimated unit water cost*

[150 million gallons per day MSF plant]

<i>Cost component</i>	<i>Cents per 1,000 gallons</i>
Capital (at 5.7 percent)-----	12. 05*
Power (at 6.2 mills per kilowatt-hour)-----	4. 55*
Materials (acids, chlorine, antifoamer)-----	4. 46*
Labor (operating and maintenance)-----	1. 15
General administrative expenses-----	0. 38
Steam (at 25 cents per million B.t.u.)-----	11. 70*
Total-----	34. 29

It can be seen from the table that 95 percent of the cost of water can be fixed. The remaining 5 percent, consisting primarily of operating labor, can be estimated fairly accurately. The guarantee on power and steam consumption would apply only to the quantities required by the plant. The costs for these items shown in table I are based on the unit cost of power in southern California and the steam cost from a commercially available steam generator. These unit costs are estimated but they are expected to be accurate within, say, 10 percent. This would translate into an uncertainty in the water cost of about 1½ cents per 1,000 gallons. On the other hand, the fuel consumption would probably turn out to be less than the guaranteed rate, so that the actual water costs stand a good chance of being lower than those shown.

The natural question to ask at this point is: How can this cost be lowered? We believe there are four ways in which this can be done.

1. Combine the waterplant with an electric powerplant.
2. Build more plant and/or test facilities.
3. Build larger plants.
4. Discover and develop a better process.

When a sea water distillation plant is coupled with a steam powerplant, both plants benefit from the more efficient use of heat. If all of the benefit is ascribed to the waterplant and depending upon the economic situation, we would expect a reduction in water costs on the order of 5 cents per 1,000 gallons, yielding a total water cost of about 30 cents per 1,000 gallons.

All of our experience in the design and construction of chemical process plants, whether ammonia, hydrogen, carbon black, polyethylene, butadiene, acetylene, or whatever, is consistent in three respects.

(a) Successive plants are always cheaper than the preceding ones.

(b) The cost of the product from a large plant is always cheaper than the product from a small plant.

(c) For a given amount of effort, greater cost reduction can be effected in complicated plants than in simple plants.

We are convinced that sea water conversion plants will not be an exception to either of these rules. Why are second generation plants cheaper than first generation plants? There are several reasons for this of which two are most important: elimination of overdesign and discovery of better ways of doing things. This process is not automatic, however, it cannot be accomplished on paper. The first plant must be built and its performance measured and analyzed before overdesign can be eliminated and innovations incorporated in the second. To a large degree, this can be accomplished in test facilities rather than in large commercial plants. It should always be cheaper to learn from a test facility rather than from a commercial plant.

The rate at which this process will effect cost reduction depends, of course, upon the rate that plants are built. If, for example, the demand for water at current prices is small, then progress in cost reduction will be slow unless accompanied by a development and test program. Progress will then depend upon the scope of the test program.

The last rule mentioned above, that complicated plants are more amenable to cost reductions than simple plants, is perhaps obvious. The situation is somewhat analogous to a comparison between a monkey wrench and a lathe. Almost every new lathe manufactured is an improvement in some respect over its predecessor while monkey wrenches haven't changed much in the last century. Because the basic process involved in sea water conversion is quite simple, a great deal of effort will be required to achieve significant cost reductions. For example, fundamental phenomena such as the flow of flashing brine in various geometries must be reexamined. Usually, some other more complicated, or novel step in a process is the dominant factor in product cost so that uncertainties in fluid flow characteristics can be compensated for by overdesign without a significant cost penalty. In the search for ways to reduce the price of converted sea water, however, we are forced to look for small improvements in how we handle fairly well understood phenomena.

To illustrate more quantitatively, the magnitude of the cost reduction which might come about through the repetitive construction of larger and larger plants, we point to the experience of the ammonia industry over the past 20 years. The process, although considerably more complicated, is still somewhat analogous to sea water distillation in that heating, cooling, boiling, and condensing operations are essential to both. Figure 4 shows the effect of increasing plant size on the cost of ammonia. The lower costs associated with the larger plants can be attributed to the more efficient use of construction materials and equipment possible in large plants rather than to any basic change in the process. This effect applies in some degree to all process plants, although some are more sensitive to it than others. We would expect the cost of a sea water distillation plant to decrease substantially with size though not as sharply as do ammonia plants.

The effect of technological improvements is illustrated by figure 5 which shows the decline in the cost of ammonia over the past 20 years. This curve has not been adjusted for the inflation which has taken place over that period so one can see that the cost reduction has been very substantial. This cost reduction has come about as the result of the cumulative effect of many slight engineering improvements incorporated into successive plants. It is important to realize that the fundamental process remains the same—no technological "break-throughs" were involved. Means were found, for example, to use materials at higher temperatures and pressures which speeded up the process so that a physically smaller plant could produce the same amount of product as its larger predecessor. More efficient methods of energy utilization and recovery were found which lowered the operating expense. The combination of the two effects shown on figures 4 and 5 has cut the cost of ammonia by a factor of 3. It is perhaps unwarranted at this time to expect a similar cost reduction in sea water distillation plant over the next 20 years. Nevertheless, a substantial reduction can be predicted, particularly if a thoroughgoing test program is undertaken.

The final factor that must be considered when speculating on methods of reducing water costs is the probability of discovering an entirely new process. Such a possibility cannot, and should not, be ruled out. The research and development program of the Office of Saline Water appears to be well oriented in this respect and all of us involved in sea water conversion follow their activities with great interest. In this statement, however, we have chosen not to speculate on the economics of those processes which have not yet reached the stage of development where cost and performance can be firmly established.

I would like to summarize with two general conclusions:

1. Large multistage flash distillation plants in combination with steam-electric plants producing water at about 30 cents per 1,000 gallons can be designed and built today; furthermore, the construction cost, performance, and water quality of such plants can be guaranteed. The cost of water produced by such plants will be far from the ultimate cost, however, because of the substantial uncertainties which exist in currently available design data.

2. We believe that substantial reductions in the cost of water produced by distillation plants will result as more and larger plants are built and as the results of test programs become available.

Senator ANDERSON: Thank you. Your company has been in the industry a long time, has it not?

Mr. DUSBABEK: Yes. As a matter of fact, we were consulting with the OSW on the uniform cost procedure back in 1954. One of the

FIGURE 4

EFFECT OF PLANT CAPACITY
ON PRODUCT COST FOR
CONTEMPORARY AMMONIA PLANTS

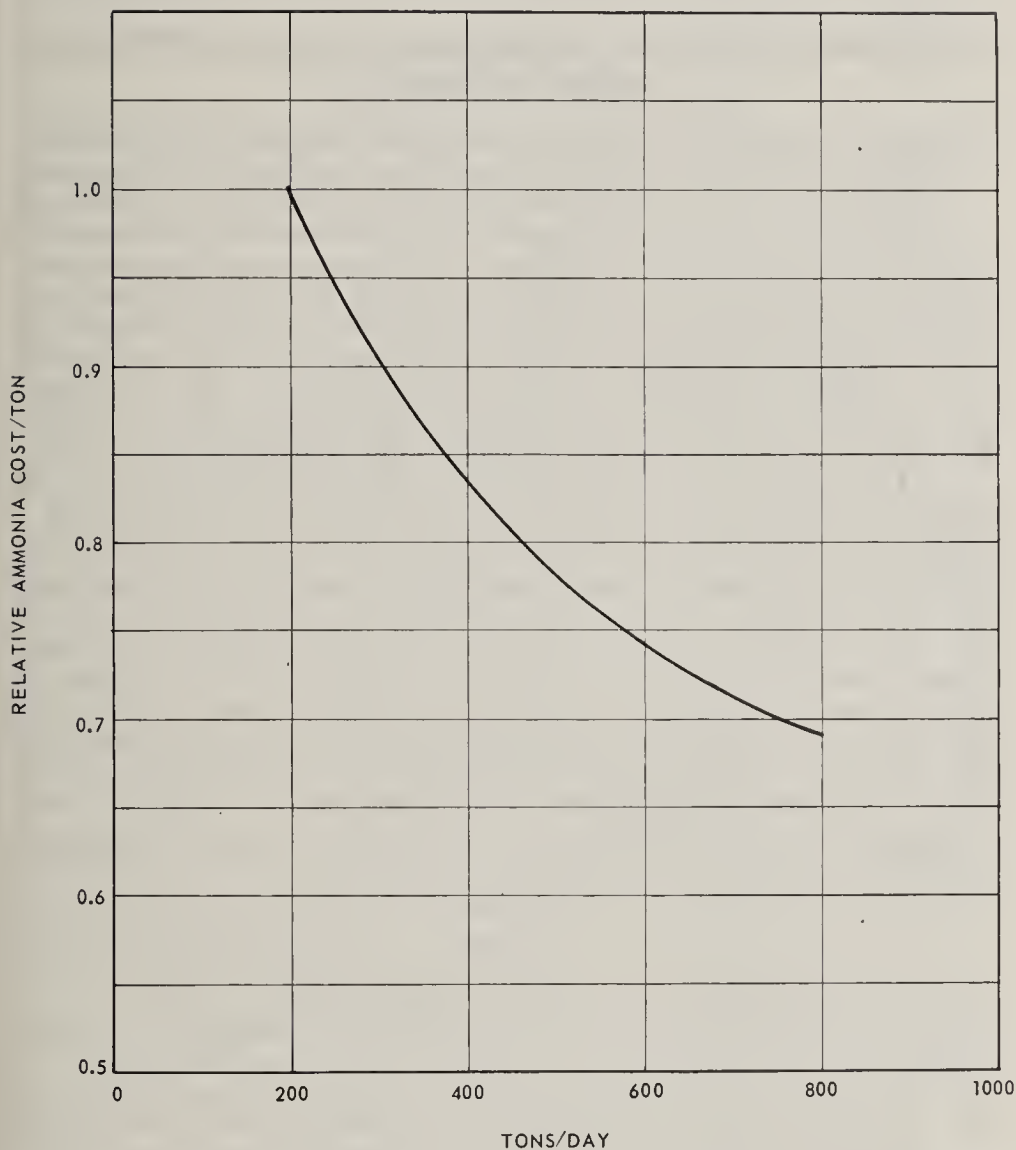
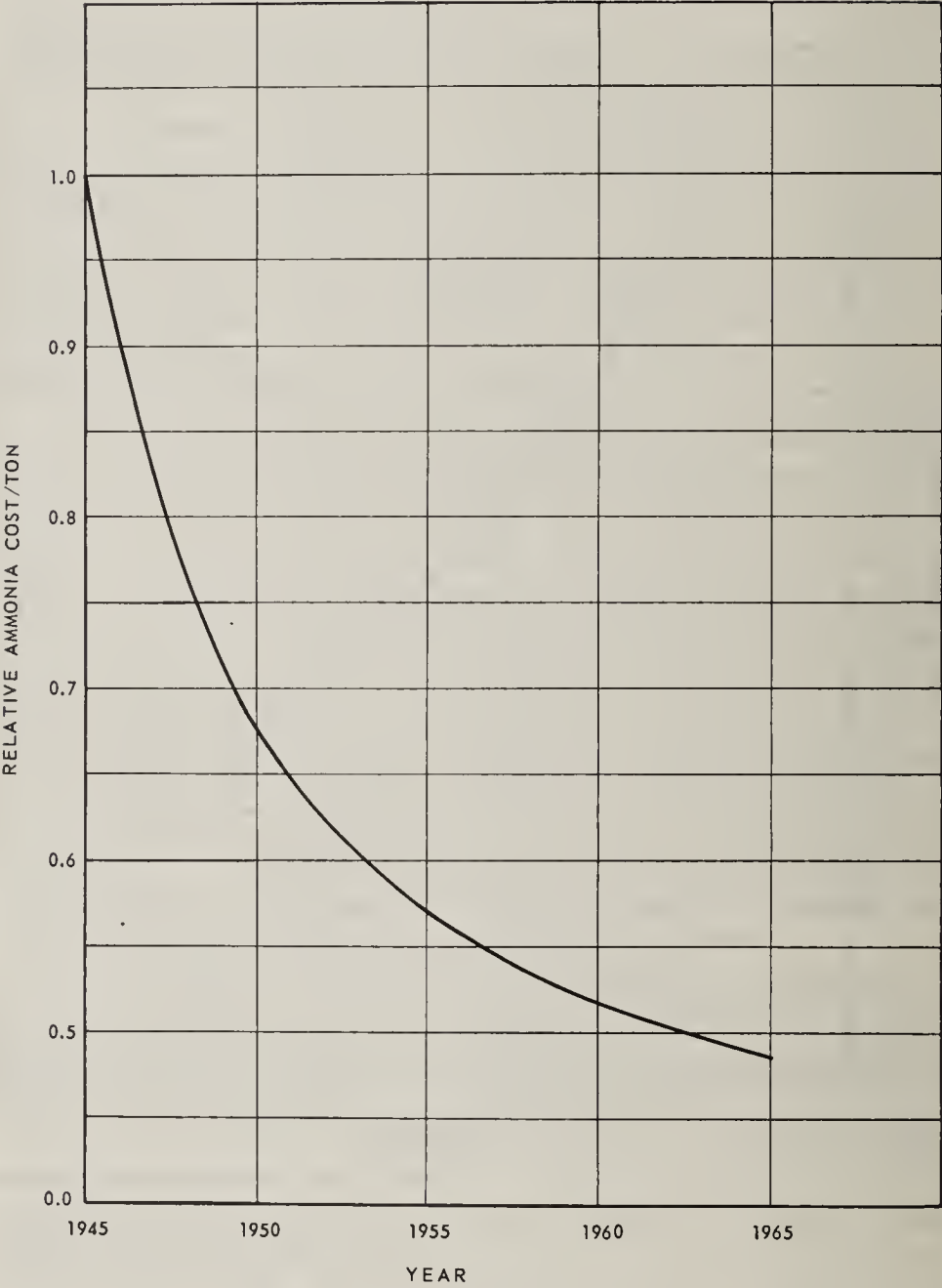


FIGURE 5

EFFECT OF TECHNOLOGY IMPROVEMENTS
ON PRODUCT COST FOR
200 TON/DAY AMMONIA PLANTS



gentlemen with OSW, Alan Silberman, I believe, directed my attention to the annual report of the Los Alamos laboratory in which Dr. Hammond had participated. From the ensuing conversation, we wound up with a study for the OSW, which we did in about 1956 or 1957.

Senator ANDERSON. I remember the name of the study and we appreciate that and we appreciate your testimony here this morning. I regret that more of the committee could not be here, but we have some votes on the floor which keep most of us pretty busy. I appreciate your being here. Thank you, very much.

Dr. Haden?

**STATEMENT OF RUSSELL L. HADEN, JR., PRESIDENT, IONICS, INC.,
CAMBRIDGE, MASS.**

Mr. HADEN. Senator Anderson and guests, my name is Russell L. Haden, unfortunately spelled H-a-d-e-n without the "y," and therefore no relation to Senator Hayden, also a member of this committee.

I am the president of Ionics, Inc., located in Cambridge, Mass. Ionics is the pioneer company in the field of electrodialysis, which is a process for removing dissolved salts and minerals from saline waters by the use of electrical energy and special plastic membranes. Electrodialysis was first demonstrated on a practical basis in the early 1950's and today is in commercial use throughout the world in more than 125 plants supplying fresh water needs to cities, industry, and military installations. The Office of Saline Water has assisted in the development of this process over the last 10 years.

Your notice of hearing stated that your committee desires testimony from many sources on the proposed expansion of the OSW program. We understand that you wish to review the accomplishments made thus far and plans for the future. Recognizing the importance of fresh water to mankind, all of us hope for a "breakthrough" which will significantly lower the costs of saline water conversion so that it will be universally useful, as President Johnson said, both to "meet our ever-growing domestic needs for water and, at the same time, provide the technology that can be shared with other nations." As enticing as this prospect is, we believe it is the consensus of experts in the field that a true "breakthrough" is unlikely and that a well-planned program of hardwork and thorough investigation to build on current technology is what is needed to further progress in these directions.

Our understanding of the program to be supported by S. 24 is taken from the report to the President dated September 22, 1964, entitled, "Program for Advancing Desalting Technology," which I will abbreviate as the Holum report. On page 7 of this report there is a chart which shows that expenditures beginning in 1966 would be 41 percent on distillation and 14 percent on reverse osmosis. No other single process comes even close to these spending levels.

The 41 percent on distillation is for sea water conversion and, hence, useful primarily for coastal communities. It is also aimed only at large plants in order to attain reasonable costs. The report of the

Office of Science and Technology of March 1964 title, "Large Nuclear Powered Sea Water Distillation Plants," projects the costs of producing pure water from sea water in such large distillation plants. The lowest cost projected for mammoth-sized plants is 26 cents a thousand gallons. I might mention here that this is made up of 19 cents for the process cost and 7 cents for the conveyance, both of which are shown separately and the sum of which is shown in that report for the cost of producing water. For very large plants, the cost is still in the range of 30 to 40 cents a thousand gallons. Such very large plants would produce 300 to 1,000 million gallons per day, equivalent to the entire domestic water needs of 2 to 7 million people. That, of course, is an incremental need.

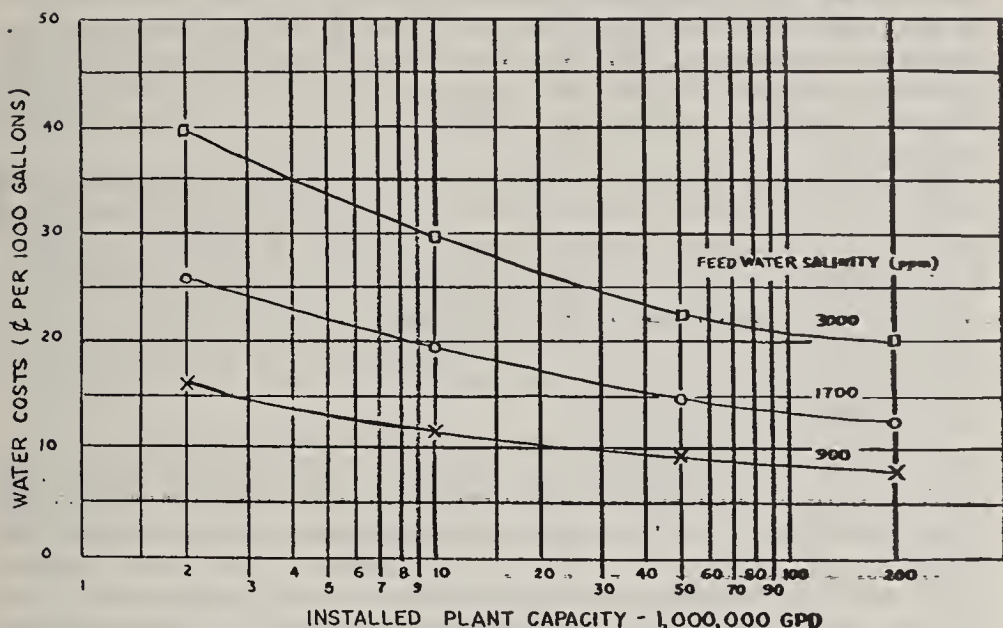
Fourteen percent of the program is to be on reverse osmosis. Reverse osmosis is still experimental or, to quote from the Holum report, is "in the early stages of development." This work is aimed at solving the needs of smaller communities and the processing of inland, brackish waters. However, Assistant Secretary Holum says, "We cannot identify with the same degree of confidence the process most economic for smaller communities." On our part, we see some real problems in depending to this extent on reverse osmosis as the solution to the needs for smaller plants on inland waters. We say this because there are still real engineering questions as to whether reverse osmosis can be scaled up from its current pure research size to a practical size and there operate at reasonable costs. Secondly, if it can be scaled up, this process is still at least 10 years away from normal commercial application as judged by past experience with development time schedules.

Therefore, we suggest that a third alternative can supplement this program, offset some of the risks in reverse osmosis, and gainfully use some of the moneys to be committed by passage of this bill. This third alternative is to accelerate the development of the electrodialysis process. Electrodialysis uses membranes as does reverse osmosis, but it uses electric current as its driving force, rather than high pressures, which reverse osmosis uses.

As I mentioned earlier, electrodialysis is currently in use in 125 installations around the world, but these are all relatively small, with the largest being less than a million gallons per day. Considering this size limitation, its costs are reasonable. However, these costs can be improved by continued research and, more importantly, we feel that the time has come for the building of a larger plant in the order of magnitude of 5 to 10 million gallons per day. A plant of this size would be 10 times the largest plant currently in operation, which is the 650,000 gallons per day plant supplying all the needs of the town of Buckeye, Ariz. A plant of this size, though large for electrodialysis, would be quite small compared to the 50 to 150 million gallons per day prototype distillation plant being studied for southern California, and the still larger plants that have been the subject of conversation this morning. Scale-up of electrodialysis by this factor of 10 would have the effect of cutting the costs of the water produced in half. Figure 1 illustrates this point.

Figure 1

ELECTRODIALYSIS OF BRACKISH WATER TOTAL WATER COSTS IN ¢ PER 1000 GALLONS



If I may digress, the chart in figure 1 gives these figures, but I also have a larger chart for the benefit of the audience if I may use it.

This chart is based upon costs which we believe are realistic and ones we would stand behind if the plant were to be built today. They make certain assumptions, of course, and the assumptions we have detailed in other reports. They are not based strictly on the Office of Saline Water's method of accounting. Dr. Hunter has requested us to supply the background and we intend to do so very shortly. But I do think they are representative of a commercial application of electro-dialysis, even though none has been built in this particular size range. If I may bring this to scale, Buckeye plant, which is 650,000 gallons a day and has a water salient slightly more saline than this middle curve—because we are operating in brackish waters and I had to have a family of curves—Buckeye is about 2,500 feed water salinity, and the size we are talking about, with 650,000 gallons a day, the cost of the water would be up in the 40- to 45-cent-a-thousand-gallon range. However, if we were to build a 10-million-gallon-a-day plant, you will see on the same size curve, we would be in the range of 25 cents a thousand gallons. Since we have prepared this curve, we have refined our figures still further and reduced them a little more in the commercial sense and I am talking very much in the range of 20 cents a thousand gallons. This 20 cents is a very attractive figure when compared to distillation, which would cost 60 to 70 cents a thousand gallons in a plant of a comparable size.

To be sure, we are comparing electro-dialysis on brackish water with distillation on sea water, but the product is the same, potable water in both cases.

The Holum report predicted need for assistance for construction of model or prototype plants. It, furthermore, stated that, wherever pos-

sible, prototype plants would be built and operated by local agencies. We feel that a community can be located with brackish water supplies, and needing 5 to 10 million gallons per day of fresh water. This community should be willing to pay the major share of the initial cost of an electrodialysis desalting plant and then to pay all the operating costs on a continuing basis. Such an installation then would not only demonstrate lower costs, but would also not be shut down once Federal support is withdrawn because it would be filling a real need of this community.

We believe that financial assistance in principle, like the grants now being made available to towns for sewage systems, might at this point persuade a community needing water to put in a desalination plant now. Otherwise, cities and towns, in our experience, are tempted to put off their requirements for desalination plants hoping for that "breakthrough," or at least for future lower costs from the Federal research program. One electrodialysis plant built now of this size will produce these benefits:

(a) We would expect that practice would result in significant reduction in operating and maintenance costs below those used in preparing the costs in the curve I have here. Since the city would be paying the entire operating costs, it would have a strong motivation to effect this reduction. Certainly, this was true of Buckeye, Ariz., which was so motivated and did reduce costs below those originally predicted. The Holum report refers to industry experience in halving of production costs of synthetic ammonia over a 10-year period. This reduction in cost was a product of increasing skill in operation and of attention to each component of cost, similar to what I suggest would happen in a larger electrodialysis plant.

(b) An order of this size would provide the incentive for private industry to enlarge membrane production facilities and lower membrane costs. These new, lower costs would not only benefit the plants already in use, such as at Buckeye, and the single larger plant proposed, but also all of the future small plants that will be needed in our inland communities. The Holum report mentions that there are over 1,000 towns using brackish water that could benefit substantially if economical, small-size desalting plants were available.

(c) A plant of this size would provide incentive to power companies to make daily offpeak electricity available at lower rates. The value of a steady bus bar load and the ease of shutdown and startup of the electrodialysis plant would be demonstrated.

Let me return to that point of over 1,000 small towns. Electrodialysis has the great virtue of being a simple process with high operating reliability. It is good for small towns in that the conscientious personnel available in small towns can do the job easily as shown in Buckeye and at Coalinga, Calif. In Buckeye, the operator spends a good bit of his day with other duties, such as repairing cars and trucks. Constant attention to the plant is not needed and no attention is provided during the two night shifts. Since it does not involve complicated, high-pressure equipment, but electricity, the local utility can be called on for help when needed.

Furthermore, the only sure, long-range source of water for most communities will be water that is reused. Water once used by a community has its mineral content increased by 300 to 400 parts per mil-

lion. Normal water treatment plants remove suspended and organic matter, but not the minerals. Mild salinity of this order of magnitude is ideal for economic processing by electrodialysis.

In summary, we suggest that the needs of this Nation and of developing nations around the world for smaller plants and for desalting of inland brackish waters should not be wholly dependent on research that may not become practical and, if it does, will need a number of years before realization. We would welcome financial assistance for a 5- to 10-million-gallons-per-day electrodialysis plant to bring such a plant within the economic ability of a community needing water today. Such a plant would:

(a) Lower costs for both medium-size and small plants.

(b) Demonstrate these lower costs and so accelerate planning for and use of desalting technology by inland towns and in smaller plants.

I might digress here and say I think this was Mr. Ennis' point, that if the lead were shown, other private agencies would follow.

(c) The Holum report quoted a United Nations' report as saying:

The water supply requirements of most of the international locations with potential for desalting would be satisfied by small plants.

This electrodialysis technology would also thus be useful to other nations.

(d) This plant would require minimum expenditure by the Government and would simultaneously establish a continuing use.

Thank you for the opportunity of presenting our views.

Senator ANDERSON. Thank you for your statement. I am very happy to have you say you believe plants of this size should be built using this process. Is this the process used at Webster?

Mr. HADEN. That is the same process, yes.

Senator ANDERSON. It has been quite successful up there, has it not?

Mr. HADEN. Well, I would defer on that to the Office of Saline Water. It, of course, is a smaller plant than Buckeye. As you can see from the shape of the curves, the costs, therefore, as reported, are appreciably higher.

Senator ANDERSON. My impression was that the people up there are pretty well satisfied with it. I think they are.

Thank you very much for coming.

Mr. Will?

STATEMENT OF ROBERT P. WILL, LEGISLATIVE REPRESENTATIVE, THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Mr. WILL. Mr. Chairman, I am Robert Will, legislative representative for the Metropolitan Water District of Southern California.

I appreciate the opportunity to appear before your committee and discuss the desalting plant study begun last December for the Metropolitan Water District of Southern California.

This study, being undertaken jointly with the Department of Interior and the Atomic Energy Commission, is to determine the economic and engineering feasibility of a combination power and desalting plant capable of producing 150 million gallons of water a day. We are indebted to the highly competent staffs of these two

agencies for their assistance and guidance and hope to continue to benefit from their abilities and their valuable research work.

Attached to this statement is a copy of appendix A of the study contract which defines the scope of the study. It is being conducted by the Bechtel Corp. and is scheduled for completion by the end of the year. I would like to discuss first some of the reasons which prompted Metropolitan to participate in this study and then describe briefly the progress we have made in these first few months.

The Metropolitan Water District is a public agency responsible for furnishing supplemental water to most of the urban areas of coastal southern California, a region with a population today in excess of 9 million people. The interest of Metropolitan in sea water conversion is not new. In 1959, the Fluor Corp. made a study for us in this regard. Its conclusions at that time indicated that the various processes still required further development and that the district should again evaluate the program in a few years. The district's interest, however, remained active and the reasons which prompted us to consider this new and promising source of water supply have become more compelling as our population spirals upward placing greater demands on our far flung Colorado River water importation system.

As an operating agency, our objectives are most directly concerned with obtaining a significant additional quantity of water for our residents. However, any advancements in desalting technology that may take place are also of great interest to us because of possible importance of desalting in the overall water picture in the arid Pacific Southwest at some time in the future.

First, it must be considered that the period prior to initial delivery of northern California water from the State water project in Metropolitan's service area now scheduled for 1971 may become critical in regard to the sufficiency of available Colorado River water to meet maximum demands for a supplemental supply. If by any chance it should happen that there were any delay in the time schedule for construction of the necessary State and district facilities, an auxiliary source of appreciable magnitude would be of great value. It appears possible that a desalting plant in the capacity range under consideration in our study could be completed and placed in operation by around 1970.

Second, the district's service area is now supplied with imported water through two long aqueducts, the district's Colorado River aqueduct and the Owens River aqueduct of the city of Los Angeles. With the completion of the initial development of the State water project, there will be a third long aqueduct supplying water from a remote source. Each of these three aqueducts crosses the San Andreas fault which is one of the most, if not the most, extensive and formidable crustal rifts on the entire globe. No cataclysmic disturbance has occurred on the San Andreas fault since 1906, but geodetic surveys tell us that crustal strains are accumulating to a degree which must be considered significant.

In the event of interruption by earthquake or other occurrence in the supply of water through any of these long aqueducts serving the southern California coastal plain, the question of an emergency supply during the outage would assume critical importance. The

available emergency sources such as terminal storage on the various aqueducts, surface storage under the jurisdiction of the various individual water agencies, and ground water storage are not evenly distributed throughout our service area. Therefore, an auxiliary localized source such as a desalting plant of appreciable capacity which could augment the other emergency supplies would constitute valuable insurance.

Third, the availability of a significant quantity of distilled water would be highly advantageous because it could be used to improve the quality of the district's water supply and make unnecessary the planned installation of water softeners at the district's new 200 million gallon per day treatment plant in Orange County. Mixing distilled water with Colorado River water would not only improve water quality but would also save some \$15 million in capital costs for these softening units plus softener operating costs of approximately \$4 per acre-foot.

Lastly, as water demands across the Nation increase, it becomes more and more imperative to develop dependable information on the cost of desalting sea water on a large scale. The possible economies to be derived from scale-up in the size of desalting units and in the size of reactors cannot be conclusively demonstrated until a prototype plant has been constructed and operated. In view of the design and construction time necessary before a large plant can become operational, we feel that it is not too soon to consider beginning work on a plant in the size range we are examining.

Since the study got underway in December some of the guidelines of the scope of work have been made more explicit so as to give Bechtel more precise objectives for analysis. Consideration as to waterplant size has been limited to one producing 150 million gallons per day of water. Light water reactors of the boiling or pressurized water types have been selected for analysis so as to take advantage of the most developed processes. The point of introduction of desalted water into Metropolitan's distribution system has been generally limited to our new filtration plant at Yorba Linda in Orange County.

Further, we have received from three southern California electrical utilities a proposal whereby they would operate the power features of the dual-purpose plant, supplying the necessary steam to Metropolitan for the operation of the waterplant and a small back pressure steam turbine generator. The power features proposed by the utilities would be double those being studied by Bechtel; they would include two approximately 750-megawatt nuclear power generating units to be financed and owned by the utilities. We will authorize Bechtel to include consideration of this in their work subject to agreement on this point by the Federal agencies.

It is still too early to report any particular conclusions from the study. The initial work has been most concerned with establishing bases to permit proper evaluation of later work, introduction of water into Metropolitan's system, disposal of excess power, and search for a suitable site.

A major portion of Bechtel's time and effort these past 2 months has been devoted to finding a site. Fourteen locations between Ventura County and the Mexican border have been investigated. These have been narrowed to three which are now under more intensive study.

Substantial land costs have also prompted an evaluation of possible offshore sites.

Because of the diminishing availability of sites, we intend to give much thought to the immediate acquisition of land for this purpose. We are fully confident that sea water conversion will play a significant part in future southern California water planning and regardless whether the district's board of directors decides at this time to move ahead on the engineering and construction of the plant, we hope to acquire the most advantageous site soon.

The study is still in its preliminary stages, and we will not be able to make an informed decision for some months on whether construction of this plant in the immediate future is justified. However, we have not hesitated to invest a substantial amount of money in this study and we are optimistic about the future of large-scale desalting plants.

Thank you.

APPENDIX A

SCOPE OF WORK

(a) The study to be conducted and reported on by the subcontractor shall be for the purpose of determining the engineering and economic feasibility and preliminary design of a combination power and desalting plant using a nuclear energy source, which plant shall be deemed suitable for operation by the Contractor by the year 1970. The study will include an analysis of combination plants with outputs of 50 to 150 million gallons of water per day and 150,000 to 750,000 kilowatts of electric power. In order to provide for periodic review and assure validity of bases or the conduct of work, the study shall be considered to be conducted in three phases as follows:

Phase I

The first phase shall consist of a preliminary survey of possible sites for producing desalted water and of means for introducing such desalted water into the contractor's system and the economic feasibility thereof; collection and analysis of water, power, and economic data necessary to establish valid bases for subsequent work; and a survey of the potential market for sale or exchange of the electric power excess to the contractor's needs for its system including its needs arising in connection with the production and distribution of the product of the desalting plant.

Phase II

The second phase, utilizing data from phase I, shall consist of a detailed investigation, including: an evaluation of nuclear hazards, of not more than three specific sites to be designated by the Contractor with approval of the Government; determination of power-water production ratios, operating flexibility, and other plant parameters based on system requirements; conceptual design of sea water intake; and analysis of nuclear reactor systems applicable to the plant requirements; total system optimization including nuclear steam supply and distillation process systems (i.e. coupling parameters); optimization of evaporator design; a comparison of the costs of energy from nuclear and fossil fuels; a breakdown of capital and operating costs of producing water and power at the site or sites selected for further study under this phase II; and a recommendation of the most desirable site and combination plant outputs based on economic and engineering feasibility.

Phase III

The third phase shall consist of preliminary design and detailed analysis of one combination nuclear plant most applicable to the contractor's system requirements and will include preliminary design and functional specifications; a detailed construction cost estimate based on vendor quotations; detailed breakdown of costs of producing water and power at the selected site as designated by the contractor and delivery of water to a point in the contractor's system designated by it; and proposed arrangements for disposition of electric power excess to the contractor's needs.

(b) The work described in phase I and phase II of the scope of the study shall be completed and a report thereof submitted to the contractor within 6 months from the date of execution of the subcontract, and a final report covering phases I, II, and III shall be completed for approval of the parties hereto within 6 months following completion of phase II.

(c) The contractor shall arrange for the subcontractor to submit within 15 days after the date of execution of the subcontract a detailed work plan identifying the major efforts to be undertaken by the subcontractor and an overall schedule of the work deemed by the subcontractor sufficient to assure completion of the three phases of the study within the periods prescribed above, which work plan and schedule must be approved by the parties hereto before the subcontractor shall be authorized to put it into effect.

Senator ANDERSON. Mr. Di Luzio, Director of the Office of Saline Water, Department of the Interior.

I am sure that I do not need to tell the witness that I welcome him before this subcommittee.

STATEMENT OF FRANK C. DI LUZIO, DIRECTOR, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY DR. J. A. HUNTER, ASSISTANT DIRECTOR, ENGINEERING AND DEVELOPMENT; DR. SHERMAN GILLAM, ASSISTANT DIRECTOR, RESEARCH

Mr. DI LUZIO. Thank you very much, Mr. Chairman.

I would like to introduce my two Assistant Directors, Dr. Gillam, who is now my Assistant Director of Research, and Dr. Jack Hunter, who is now my Assistant Director for Research and Development. I am sure that between the three of us we can answer any questions that may come up.

My statement is rather lengthy, but to reduce it in size I may not be responsive to the many issues which have been raised.

Senator ANDERSON. You go right ahead.

Mr. DI LUZIO. Thank you, sir.

Mr. Chairman and members of the committee, during the first decade of the operation of the Office of Saline Water, from the enactment of the Saline Water Act of 1952 by the 82d Congress until the Anderson-Aspinall Act was approved in 1962 by the 87th Congress, appropriations for research and development totaled only \$7.5 million, or about \$835,000 per year. Most of these limited funds were spent on general engineering studies.

The basic research program was so limited it was practically nonexistent. Following the enactment of the Anderson-Aspinall Act, a vigorous program of fundamental research work was developed and it has provided a respectable amount of valuable basic data.

The progress report dated February 1964 of the Committee on Water Resources Research of the Office of Science and Technology defines research as follows:

Research is systematic, intensive study directed toward fuller scientific knowledge of the subject studies. Such study covers both basic and applied research.

To me, the two key words in that definition are "applied research." The report also provides the following definition of development:

Development is the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, or methods, including design and development of prototype and processes. It excludes quality control or routine product testing.

The thrust of our immediate program falls within these two definitions. As we have analyzed the character of the program, it has become obvious that merely developing theoretical processes or carrying the development of a process through the prior plant stage of development does not provide the total data necessary for engineering decisions.

Prototypes are necessary for the full development of any chemical process and when one adds the stringent economic parameters that must be known for a desalting plant, it becomes clear that we must anticipate construction of desalting prototypes to field test engineering design and process characteristics. We consider our short-range program to be a difficult, but surmountable, engineering challenge. The Secretary has presented a general review of program developments to date. However, independent analysis has been going on and will continue as I will detail later.

I would now like to describe in detail the program we propose to undertake from this point forward. I do not intend to discuss the accomplishments or failures of the past, as my responsibility and major effort is concerned with the present and the future. In order to fully provide the committee with a comprehensive report of the accelerated program we propose to undertake, I shall endeavor to set forth clearly and concisely our goals and provide you with a skeleton outline of the strategy we have devised to achieve these objectives.

Several members of my technical staff are here with me today and following my remarks I shall call on them to submit for the record specific details of the programs we will pursue to transpose strategy into action, and to present orally the highlights of their prepared statement and, of course, to answer any questions which committee members may raise.

I assumed my responsibilities as Director of the Office of Saline Water during a time when the scope and thrust of the saline water conversion program was in a period of transition.

In order to acquaint myself fully with the broad challenges presented by the assignment and by the program, I have made a rather exhaustive study and review of past activities in order to determine in my own mind answers to such questions as: What is the technical development status of the program today? What are or should be the relations of the Office of Saline Water with private industry? With other Government agencies? With the scientific community and with the States? What kind of organization does the Office of Saline Water need to implement the water program? Organizational changes already made are shown on chart A. As to the comment made earlier by Dr. Tribus about an engineering advisory committee, we are now selecting qualified persons for just such a committee. Its services will not only be used by myself and my senior engineering advisers, but also by Dr. Hornig whenever he reviews our program. In other words, what are the technical, social, political, and economic implications of the program, both here at home, and to some extent, abroad?

Some of these answers have been easy to come by, others have not yet been satisfactorily resolved, especially some of the technical aspects of the program as they relate to current research and development activities on various conversion processes. To help me obtain some of the information, I still need to translate the President's imagi-

native program into scientific and technical action, I have appointed a highly competent group to undertake a thorough and hardheaded engineering review of all processes, by category. This review is underway on the freezing processes to ascertain their scientific merit, their economic potential, and their practical application. Similar reviews will soon be undertaken for all the other processes.

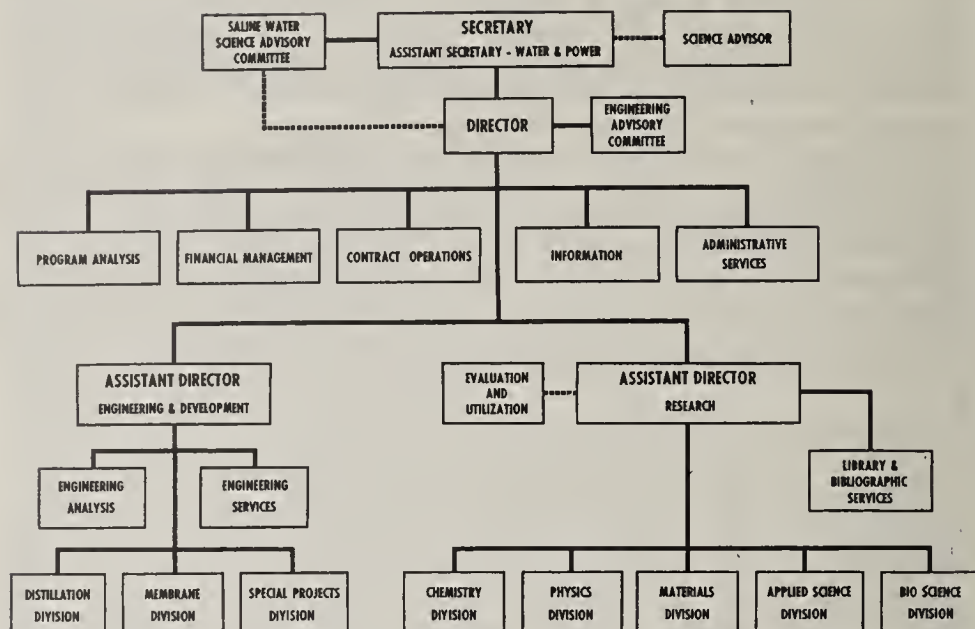
When this information is compiled and analyzed, we will be better able to assign priorities to promising projects, reduce the level of effort in some areas of research and development, and terminate development work on processes that do not warrant further support. We will also be in a better position to refine our program and identify specific features not authorized by the pending legislation. A list of the review groups and their membership is submitted for the record in attachment A. We must direct effort to new areas of engineering development on equipment and major components such as pumps, deaerators, heat exchangers, turbines, valves, vapor compressors, et cetera. A bad hydraulic system or an inefficient deaerator may so penalize an otherwise efficient plant that it will not achieve its true potential. On the other hand, a costly development of a new heat exchanger or work to improve the rate of heat transfer by 10 percent may not be worth the effort in terms of product water cost. The Office of Saline Water has used existing facilities and talent of other Government agencies in the past, and we expect to increase this phase of our program in the future. We have neither the time nor the inclination to try and obtain our own research facilities.

Work has been carried on at the Bureau of Standards and we have exchanged information and coordinated programs with the Department of Defense and the Department of Health, Education, and Welfare. We are expanding the work we sponsor at the Oak Ridge National Laboratory, we have received a proposal from Brookhaven, we have discussed with the appropriate officials the possibility of conducting work at the Atomic Energy Commission facilities at Hanford, Wash.; Los Alamos, N. Mex., Scientific Laboratory; and Sandia Corp. We have, and will continue to utilize and work with other bureaus and agencies of the Department, including the Bureau of Reclamation, the Bureau of Mines, U.S. Geological Survey, and the Office of Coal Research. We expect also to coordinate with the Office of Water Resources Research.

The factors that influence the cost of water to a customer fall into two main areas: First, factors that occur "within the skin" of the plant itself, engineering optimization of such effects as heat transfer rates, steam temperatures, chemistry of feed water, scaling, corrosion, fuel cost, construction costs, and many other factors. The second set of factors are those outside the characteristics of the desalination plant. These include the cost of money; the amount of water needed for a specific area—that is, size of the plant; the availability of a properly sized storage and distribution system; the geographical need for large blocks of power in the case of a dual-purpose plant. Much too often we concentrate on the first set of factors, and ignore the second.

Relative to the economics of sea water desalting, chart B interrelates quite well, I believe, in an approximate manner, the current economics of a wide spectrum of water uses, the complexity

CHART A



of our mission to develop the technology for desalting systems which meet or better these economics to serve each of the needs shown and an order-of-magnitude estimate of each time period by which we expect to have desalting units that meet these capacity ranges and water costs. It may be seen that our current status of desalting development has brought us to the stage where desalting plants of American design and manufacture can be purchased and installed to economically serve the fresh water needs of small communities—upward of 5,000 population—isolated from natural fresh water supplies. By 1968–72, we expect to have developed and field tested the technology to support the manufacture and sale of desalting plants big enough to supply the industrial and residential needs of larger communities, those in the range of 10,000 to 50,000 people.

By 1970–75, we believe that the desalting technology to be gained from the expanded program, for which we are testifying in behalf of the enabling legislation today, will have demonstrated that American industry can furnish municipal water production plants from sea water and supply sources and brackish water pools at costs which will make such incremental water supply systems competitive with alternative fresh water sources based on today's economics and, in many cases, the logical source for an additional water supply.

I have been eliminating wherever I possibly can the word "competitive." I do not think that the plants we are producing, or hope to produce, are really competitive in the true sense of the word. I think they are plants which may be the only answer, both economically and in terms of furnishing water for a community. I do not like the term "competitive," because this sounds as though we are competing with other water sources, and this is not what I intend.

OFFICE OF SALINE WATER

EXPLANATION OF ORGANIZATION CHART

The level of effort which the expanded program envisions and the emphasis we will place on engineering and plant construction has carried with it the need to effectuate major revisions in the organization structure of the Office of Saline Water. We will also need additional personnel with experience and expertise to carry out the program mission with optimum efficiency.

Up to this time, a major activity of the Office has been to stimulate interest and disseminate information, study the economic potential of available processes and explore the possibility of developing new methods of desalination.

The present state of the art has reached a point where the future thrust of the program must be recast, placing primary emphasis on engineering. This will enable us to develop the hardware needed to improve and implement the utilization of processes and components which merit further enlargement and improvement. The administration of a program which includes the engineering developments leading up to and including the construction of a 50-million-gallon-per-day plant will obviously require many diverse talents not previously needed by the Office.

The former organization of OSW was a horizontal pattern consisting of three technical divisions; namely, the Division of Research, the Division of Processes Development, and the Division of Demonstration Plants. There was also a fourth division for contracts and administration which included everything from housekeeping services to auditing. All of these divisions reported directly to the Office of the Director.

The new OSW organization is devised to provide a systems management approach to efficient program execution. The direct line of responsibility funnels from the director through three principal areas of program responsibility and authority; namely, "development and engineering," "research," and "administrative services." The development of processes has been divided into three operating divisions: distillation, membranes, and special projects (freezing, hydrates, and special components). Staff and administrative services have been segregated to conform more clearly to definite functional responsibilities. A program analysis staff has been established to insure continuous component review of the program to assist the director in maintaining a proper balance of effort and coordination of programs. A refined water economics program will enable us to acquire competency in this highly complex area. Steps have already been taken to establish a highly component outside engineering advisory group to augment internal engineering competency.

CHART B

TIME PERIOD	WATER COST \$/1000 GAL (SEA WATER)	TYPE OF UTILIZATION	TYPICAL PLANT SIZE MILLION GALS. PER DAY
1952	5.00	Remote Small Community (e.g. Islands) Tourist or Export Economy	0 - 0.2
1965	1.00	Isolated Small Communities Industrial Economy	0.2 - 1.0
1968 - 72	.50	Small Communities Industrial & Residential	1.0 - 10.0
1970 - 75	.25	Large Municipalities Developed Economy	10 - 150
BEYOND 1975	.12	Agriculture - High Value Crops	150 - 1000
	.06	Agriculture - Low Value Crops	1000 - Up

Relative to the time when we expect desalting technology will be far enough advanced to compete economically in the irrigated agriculture water market, our best guess today would have to be "after 1975" as we have shown, unless we achieve a major technical breakthrough not now predictable.

Dr. Hornig stated that theoretically a breakthrough is possible, but it is a very difficult practical problem. Dr. Philip Hammond is very optimistic about being able to produce water some time at prices between 12 and 6 cents, but we have no target at this time and no program pointing in this direction. We are trying to do it step by step somewhat along the line of Dr. Tribus' testimony.

Dr. Tribus seems to have some erroneous concepts of our program. He apparently assumes we are talking about building a 150-million-gallon-per-day plant. We are not. Such a plant will be built only when there is a customer interested in the product and willing to participate financially in its construction. Therefore, it must meet the test of the marketplace.

Relative to planning for additional water supply within any given geographical region, it is essential that such a study be based on careful appraisal and evaluation of the engineering, economic, and financial feasibility of the alternative sources of supply, and combinations thereof, as well as the evaluation of less tangible but important and perhaps controlling factors such as political and sociological effects.

There are a number of important considerations which must be analyzed whenever we talk about siting a water plant in a large comprehensive scheme, particularly the alternative methods of providing water.

ATTACHMENT A

COMMITTEE FOR EVALUATION OF THE FREEZING PROCESS

- Dr. Allen J. Barduhn, Department of Chemical and Metallurgical Engineering, Syracuse University Research Institute, Syracuse, N.Y.
Dr. P. L. T. Brian, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Prof. T. K. Sherwood, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

RESEARCH REVIEW BOARD

- Dr. K. S. Spiegler, Sea Water Conversion Laboratory, University of California, Richmond, Calif.
Dr. Henry S. Frank, Mellon Institute, Pittsburgh, Pa.
Dr. Charles L. Thomas, Sun Oil Co., Marcus Hook, Pa.
Prof. E. R. Gilliland, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Dean Ralph A. Morgen, Stevens Institute of Technology, Castle Point Station, Hoboken, N.J.

COMMITTEE FOR EVALUATION OF DISTILLATION PROCESSES

- Dr. Myron Tribus, Thayer School of Engineering, Dartmouth College, Hanover, N.H.
Dr. B. F. Dodge, Department of Chemical Engineering, Yale University, New Haven, Conn.
Mr. Ed H. LeBeis, Jr., Media, Pa.
Dr. A. E. Dukler, Department of Chemical Engineering, University of Houston, Houston, Tex.
Mr. Paul Buckingham, the Fluor Corp., Ltd., Los Angeles, Calif.

COMMITTEE FOR EVALUATION OF REVERSE OSMOSIS

- Dr. Ulrich Merten, General Atomic Division, General Dynamics Corp., San Diego, Calif.
Prof. J. W. McCutchan, Department of Engineering, University of California, Los Angeles, Calif.
Dr. Alan S. Michaels, president, AMICON Corp., Cambridge, Mass.
Dr. B. Keilin, head, Chemical Resources Department, Aerojet-General Corp., Azusa, Calif.
Dr. Kurt A. Kraus, Oak Ridge National Laboratory, Oak Ridge, Tenn.

A major prerequisite to the development of sound alternative plans for fulfillment of additional water supply within a regional geographic area is, of course, the establishment of the future time period for which the plans are being made and over which the new facilities are to be amortized. The phasing of a water supply program will have a major impact on the economics of the alternatives and could spell the difference between choosing, for example, a major inter-basin pump-transfer plan or a single basin plan involving the construction of desalting plants to serve the coastal regions supplemented by the construction of high-head storage reservoirs to serve the regions at the higher elevations. Thus, all alternative sources of additional regional water supply must be considered.

What this means, in short, is that the Office of Saline Water cannot by itself develop a regional water plan. It must be done in conjunction with the Bureau of Reclamation, the Corps of Engineers in some cases, the Geological Survey, and State water agencies.

The evaluation of all possible alternatives to arrive at an optimum regional plan is a difficult task which will require much care and consideration. For example, the evaluation of the alternatives of fresh water redistribution and sea water desalting will require a careful assessment of the cost of delivery of these alternative water sources to all points to be served within the region to determine the economic boundary lines. This table (attachment C), lists the input data required and the decision steps necessary for economic optimization of a given site. In certain areas, the economics of reclaimed waste water must also be analyzed and understood.

We have awarded contracts to experienced architect-engineering firms to conduct cost studies on large nuclear-powered combination steam-electric and water desalting plants. In addition, in January of 1963, Dr. Jerome B. Wiesner, then Director of the Office of Science and Technology, appointed a task group to investigate the use of large nuclear reactors for producing electric power and heat for sea water distillation. Our contract studies were conducted by the Fluor Corp., Ltd., Bechtel Corp., and Catalytic Construction Co. The first of these was conducted by Fluor in 1959. Based on the technology available at that time, Fluor estimated the cost of potable water produced from sea water in a single purpose 50-million-gallon-per-day 52-stage flash evaporator (when steam is supplied by a 370 thermal megawatt, pressurized water, nuclear steam generator) to be \$0.42 per thousand gallons.

The Bechtel Corp. cost studies of large multistage flash saline water conversion plants was undertaken to determine the extent to which the cost of converting sea water to fresh water could be reduced as a result of: (a) increasing the scale of operations to very large size and (b) using exhaust steam from a gas-fueled power generating station to supply heat to the sea water conversion plant. Without going into all the basic factors that were assumed for this study by Bechtel, the cost of power was calculated to range from 3.11 mills per kilowatt-hour to 3.89 mills per kilowatt-hour. Water costs ranged from 34.2 to 44.9 cents per 1,000 gallons.

The Catalytic study considered a wide range of variables for both power and water production. Water costs ranged from 28 to 55 cents per 1,000 gallons and power costs were computed as low as 3.05 mills

CHART C

ECONOMIC OPTIMIZATION FOR A GIVEN SITE**INPUT DATA REQUIRED**

1. Water Needs
 - a. Time phasing
 - b. Quantity
 - c. Quality
 - d. Demand schedule
2. Power Needs (if any)
3. Alternative Sources of Fresh Water and Incremental Cost
4. Water Storage and Distribution Capacities
5. Saline Water Availability
6. Brine Disposal Possibilities
7. Cost of Energy
8. Value of Incremental Water

DECISION STEPS

1. Select Water Source
2. If Desalting Selected, Determine:
 - a. Plant size
 - b. Public or Private funding
 - c. Dual or single purpose
 - d. Location
 - e. Desalting process
3. Determine Cost of Incremental Water
4. Recycle

per kilowatt-hour. The Office of Science and Technology Task Group stated in its report:

Our basic conclusion is that, following an orderly development program that appears entirely feasible, water can be made available from combination plants in coastal areas in large quantities at prices that are reasonable to pay for municipal and industrial purposes. Stated more specifically—

the report continued—

combined installations producing 1,000 to 1,500 megawatts of marketable electrical energy and 500 to 800 million gallons of water per day, with the water costing 20 to 25 cents per thousand gallons at the plant site (exclusive of conveyance costs) and the electric power valued at 2.3 to 2.5 mills per kilowatt-hour, can be envisioned by about 1975 if an appropriate research and development program is actively pursued.

It is interesting to note that since these figures have become available, 3 mill power from fossil fuel plants is now available. In fact, dump load power has been offered to the State of California at that price.

The economic studies we have conducted to date have been able to consider only a small fraction of the overall problem. It is not always practical to attempt to assign a reasonable market value to water. One thing is absolutely clear—there is no water as expensive as no water. Each summer we read of water use restrictions imposed by various municipal governments. We can expect to read about, or perhaps even endure, these restrictions so long as periods of drought or extended heat waves cause supplies of fresh water to be consumed at a faster rate than our natural sources can provide.

The cost of water itself becomes less important when considered in the light of the economic impact of water rationing. Many industrial plants require great volumes of water for processing, and water use restrictions can cause production cutbacks which diminish profits and paychecks.

But even more important than economic considerations is the relationship of water supply to human needs, especially the detrimental effects on health that can result from water shortages. Inadequate supplies of fresh water serve to compound pollution control problems. Without sufficient water for dilution of the effluents we pour into our rivers and streams, they can become so choked with pollutants as to lose their natural ability to regenerate the water to a usable condition. To alleviate this adverse situation, we suggest that it is now time for saline water conversion plants to be considered as a practical supplemental source of fresh water supply.

We do not intend to imply that the Office of Saline Water should enter the water supply business through the construction and operation of desalting plants, but we do recommend that the technology which is now available be utilized advantageously. To accomplish this, the Office of Saline Water is prepared to provide technical assistance to other governmental agencies.

Federal programs to make water available are now being conducted by the Bureau of Reclamation, the Corps of Engineers, the Department of Health, Education, and Welfare, and the Housing and Home Finance Agency. These programs include such activities as the construction of dams to create fresh-water reservoirs, grants or loans for sewage and water treatment plants, distribution facilities, et cetera.

As a specific example, the Housing and Home Finance Agency recently provided a grant and loan to the Port Mansfield Public Utilities District of Raymondville, Tex., for a complete water treatment facility, consisting of a water supply well, iron and manganese removal filters, two 100,000-gallon concrete storage reservoirs, and a 250,000-gallon-per-day electrodialysis process desalting unit. The HHFA contacted the Office of Saline Water for general technical advice in the selection of the process to be used at Port Mansfield. Unfortunately, no contractual provision was made by HHFA to provide for the availability of technical data on the operating characteristics of this plant to our Office. Such data can often provide valuable "technological spinoff" and in all future projects of this kind we will strive to obtain arrangements which will provide us with such data.

I would like to comment on Dr. Haden's statement about electrodialysis. I do not think he intended to imply that electrodialysis has no problems; it does. It is operating well in Arizona because of the chemical characteristics of the water. It is operating well in Webster, S. Dak., but it is taking a substantial chemical engineering effort to learn how to pretreat these brackish waters so that the process will operate efficiently. I think the plant Ionics is building at Port Mansfield will do all right, but we must develop better iron manganese removal filters. When iron manganese is present in brackish water it will foul up the electrodialysis membranes. I think this process has a great future. It is one of the oldest processes we have, but it still needs further development.

We are not advocating any new loan or grant programs. The mechanisms for this type of assistance may already be vested in other agencies. But we would like to have the opportunity to participate in the design, construction and operation of conversion plants or at least to receive, as previously mentioned, technical and economic data from plants which are built or funded by other governmental programs.

We do not intend to spend appropriated funds on the development of any process unless we can be reasonably assured that it will better meet a specific need than any other process. Our continuing critical analysis of processes potential may require us to reevaluate some of the strategy we now plan, but this is normal in any progressive activity. We must remain flexible and ready to exploit any advantageous shift that may develop as a result of the research and development we sponsor.

Eventually, we shall have to decide which process has the greatest possibility of being scaled up in size. We soon must decide how many methods we can support to make fresh water out of sea water in the 30-40-cent price range. There may be three or four different ways of doing this, but we should emphasize only the process which has the greatest potential of future cost reductions.

The present authorization of the Office of Saline Water, Public Law 87-295, contains the following statement:

As used in this act the term "saline water" includes sea water, brackish water, or other mineralized or chemically charged waters.

We intend to work on the development of processes which will have application for demineralization of all types of waters contained in

that definition. We especially intend to increase our activity in brackish water areas, and take a hard engineering look at the potential application of desalting processes on acid mine waters, in tandem with the effort on large plants. We propose to maintain a balanced program. This is what we keep repeating over and over again. We are not going to sacrifice reasonable expenditure of funds in these other areas which are also the responsibility of the Office merely to put on a spectacular. I know how the chairman feels about spectaculars, and this program is going to be a balanced program. Whatever program we get, we are going to push the technology for each of the processes a reasonable degree and we are not going to sacrifice some good idea merely because we want to make a show with something else.

I would find it difficult to assess priorities to small- and medium-sized brackish and sea water plants on one hand and large single- or dual-purpose sea water plants on the other. There are many valid reasons that have prompted us to reach that decision. Brackish waters is a term we use to describe a broad range of salt polluted water. The Public Health Service has established standards that good drinking water should contain not more than 500 parts of dissolved salt per million parts of water (500 parts per million) and further, that water containing more than 1,000 parts per million of dissolved salt should not be used for human consumption.

Potential users of saline water conversion plants (100,000 gallons per day and up) include municipalities and other public or private water utilities providing water supplies to domestic, institutional, commercial, or industrial users. These may use desalting facilities to supplement an inadequate existing water supply, to improve the quality of an existing supply, or for both purposes. It is anticipated that cost competitiveness with water from conventional sources will not always constitute the first limiting factor to the utilization of saline water resources. Eventually, every major water utility may incorporate a desalting unit in its treatment plant. A water-quality conscious population is likely to insist on higher-than-minimum water-quality standards.

Industry has water-quality requirements which may be quite different from those of residential water users. Cooling water can be less pure than potable water. Boiler feed water, water for chemical processing, and water for canning and soft-drink production must be substantially purer than most potable water. Thus industry may profitably employ additional demineralization equipment as the economics of demineralization systems are improved.

Our present sewage treatment methods allow water still very high in nutrients to go back into the streams. This is causing some serious problems in our rivers. It seems to me that water pollution control and desalting technology may well fit hand in glove and perhaps a multiapproach to the water pollution problem and desalination problem would make some sense.

As an example, officials of a New Jersey town, which wanted to build a desalting plant, came to us for advice. They told us that they had to pump fresh water back into five or six wells in order to stop salt water incursion which threatened to contaminate the well field. They wanted a 5-million-gallon-per-day plant to provide the

water to recharge these wells. It would be very high-cost water for this purpose. At the same time, they daily would be wasting one and a half million gallons of sewage to which they give only primary treatment and then dump into the bay. This practice has ruined their shellfish industry.

The idea that we proposed to them was that perhaps they needed secondary and tertiary treatment to their sewage to make it reusable. By using the reclaimed waste water plus a reasonably scaled conversion plant that can provide water for peak demands they might find a better all-around answer to their problems of salt water incursion, pollution control, and fresh water supply. The Department of Health, Education, and Welfare is working with them now to study the situation.

The Government, including the military and civil defense, also is a prospective user of desalination facilities. Additionally, power utilities may wish to expand the market for their product by building and operating dual-purpose desalination plants. Sewage treatment for municipal water reuse may need to be complemented by desalination, especially in closed-cycle, indefinite reuse, water systems.

We are looking very hard at existing heat sources as a potential supply of energy. We are studying our process in combination with generating plants to see if a distilling unit can be associated with that type of existing heat source to produce water at a low price. I think it has a very good economic potential. Another good possibility is the heat available from the burning of waste. There are many cities with rather large incinerators which burn this material. Perhaps the association of a large incinerator with a water processing plant will make good economic sense.

Pollution abatement for America's streams represents a need which may be met in part through desalting facilities. Whether the pollution is due to sewage or treated sewage effluents, to industrial wastes, or to acid mine drainage, it is probable that saline water conversion techniques will find applicability in the scheme of cleaning up rivers and lakes.

The reverse osmosis process has been examined by HEW as a pollution control measure. I believe many of our processes will be at least part of the answer to pollution control.

A number of foreign countries have an urgent need for desalting facilities. In some areas, the limitation of cost competitiveness has been removed because potable water resources are not within reach. The desalination of brackish waters presents a variety of problems, but more importantly, it also provides some exciting opportunities. First of all, there is an enormous amount of brackish water readily available in the United States; second, much of this water is available in areas where natural fresh water is in short supply and some distance from possible users. Third, most brackish water is in the salinity range (1,500 to 6,000 parts per million) which may be desalted and put to practical use at a feasible price.

To expediate our investigation of the applicability of sea water desalination techniques to brackish water treatment, we will propose to establish a test center for brackish water similar to our Sea Water Conversion Research and Development Test Station at Wrightsville Beach, N.C. Our experience at Wrightsville Beach has established

the value of such a center to carry out efficiently the large pilot plant and test bed phases of our development program. Because of the nature of the processes applicable to brackish water desalination, the size of the brackish water test center and equipment will be much smaller than that of our Wrightsville Beach Test Center.

The reason I think this is very important, Mr. Chairman, is because of the fact that most of the data we have developed on processes of brackish water desalination have been extrapolated from sea waters. We find the chemistry of brackish waters is much different from that of sea water. It runs into such things as silicon, iron, manganese, and so forth, that rather than have to face up to the problem of desalination, it may be much cheaper to come up with a cheap process to condition the brackish water before it goes into the facility. This, I think, should be a very active program and we should increase its momentum, because I think it has great potential.

Engineering evaluations and whatever other studies or activities may be necessary to determine the potential use of desalting processes for the reclamation of acid mine waters which are choking the rivers of Appalachia will be forthcoming: in fact, some engineering evaluations in cooperation with the Bureau of Mines and the State of Pennsylvania are already underway. We have moved into this area.

While desalting plants are now producing fresh water on a commercial basis at a number of locations where water is in short supply and very expensive or where the quality of water is poor, the cost of desalted sea or brackish water today is still too high for general municipal and industrial use.

Our charter, as set forth in the Saline Water Act of 1952, is to develop processes for the low-cost conversion of saline waters to fresh waters for beneficial consumptive purposes. Thus our program will center on plants based on a variety of processes and in several sizes to meet the variety of water problems previously enumerated, and at as low a cost as time and technology will permit. Relative to economics, when we speak of low-cost desalted water we do not infer that it is low-cost water. Natural fresh water in situ and transported with conventional civil works systems is such an inexpensive commodity it is probably today's best bargain.

The average price for municipal water supplies in the United States today—delivered—is about 35 cents per 1,000 gallons, or to express it another way, about 10 cents a ton. I would point out, however, I used the word "price," not "cost," as we do not have reliable data on actual cost. Fresh water from ocean water may never be that cheap in price, but the cost of natural fresh water is rising, as competition for the available supply grows keener.

It is unlikely that desalted water will ever be a replacement for readily available natural fresh water until natural water supply sources become so distant from the customers that the increased costs of transport and distribution systems raises the cost of natural fresh water above that of desalted water. However, the need to augment existing sources of natural fresh water supply exists now in some of the water-short areas of the country.

Basically, these are the Western States and some cities on the east coast. To make such supplemental supplies available at reasonable cost is an extraordinarily difficult assignment.

As the Secretary has already testified, our expanded program will place greater emphasis on engineering problems and the development of hardware for prototype plants ranging up to 50 million gallons per day. If there is one single important difference between science and engineering, it is the fact that an engineer worthy of the title must be concerned with the cost of things and not just the technical applicability of a process.

In the conduct of a program of this magnitude and scope, we can predict that the leading engineering concepts which evolve will need to be tested and proved out in prototype intermediate-size plants or in modular fractions of plants scaled for 50 million gallons per day or larger. But the engineering data presently available are too meager to enable us to forecast at this time the specific need for legislation to support such activity. In this situation, we will perform the applied research and engineering development work leading to the preliminary engineering or scope design of such plants and then make decisions on the need for additional legislation when we can more clearly identify the prototype plant requirements.

To make progress toward our expanded program objective, we propose a three-prong attack with short-, intermediate-, and long-range goals. Our short-range goal is to provide processes and plant designs with the lowest possible desalting costs at the earliest possible time. To accomplish this, we must undertake a dynamic engineering effort to analyze the significant amount of research and development technology acquired in this program to date and to choose that which is best for immediate incorporation into the conceptual design of a desalting plant sized in the range of 50 million gallons per day. Our intermediate-range goal will be aimed at the development and pilot plant demonstration of hardware components having the greatest technological potential for utilization in the 50 million gallon per day plant while concurrently developing and pilot testing hardware components applicable to new processes now emerging from laboratory and bench-scale operations. Also, modifications and improvements of existing processes will be conducted at the pilot plant level to provide the data we must have to fully determine the technical merit and economic potential of new approaches.

The reason this is broken down into three phases is, one, the first phase is actually an engineering problem and using existing technology without waiting for any scientific breakthroughs; merely the better use of materials, the better design of plants and getting low-cost energy. The intermediate range will involve this kind of improvement plus some rather good engineering data on new materials, and new designs.

As we proceed with these short- and intermediate-range programs, we will also concurrently support a long-range scientific program of basic research. In the pursuit of these fundamental studies, we will be alert for revolutionary new concepts which could emerge to offer the promise of further reductions in the cost of desalination.

This chart—chart D—represents, by percentages, the distribution of funds required to maintain a balanced program. This distribution is necessary in order to obtain maximum benefits from the short-, intermediate-, and long-range programs we have planned. Any sizable deviation from this distribution would tend to overemphasize one function at the expense of another.

CHART D

DISTRIBUTION OF PROGRAM FUNDS BY FUNCTIONS (IN PERCENTAGE)

	Fiscal Year 1967	Fiscal Year 1968	Fiscal Year 1969	Fiscal Year 1970	Fiscal Year 1971	Fiscal Year 1972
Administration	4	3	3	3	3	4
Program Analysis	2	2	2	2	2	3
Research	23	20	27	26	26	35
Eng. Analysis	1	1	1	1	1	1
Eng. Services	8	5	7	6	5	5
Distillation	40	51	35	36	40	24
Membranes	13	10	13	14	9	10
Special Proj.	9	8	12	12	14	18

This next chart—chart E—is a very interesting one, because it shows 56 percent of the money in the short range, which is the period from now through the next 6 years. Actually, a good portion of that 56 percent is the cost of hardware. In terms of technological work, both in engineering and science, membrane processes are receiving fair attention and special processes, which are the freezing and hydrate processes, are also receiving a fair share of attention. Some of these processes are too far downstream to require hardware, but they represent potential low-cost processes.

The established target for the short-range distillation program is to conduct the development work which will provide the technological information and engineering data that we must have to initiate the construction of a 50-million gallon per day plant or larger in 1968. Throughout the short-range program, we will continue to press forward with the development of improved technology on processes other than distillation that will be needed to meet a variety of water supply problems.

The percentage figures we are providing the committee today can only approximate the rate of expenditures for the years ahead. They are not precise simply because we cannot foretell the rate of technological

CHART E

FUND DISTRIBUTION AS TO FUNCTIONS BY SHORT INTERMEDIATE AND LONG TERM GOALS

	Percent Short Range	Percent Intermediate Range	Percent Long Range
Distillation	56	48	..
Membranes	8	20	6
Special Projects	3	10	36
Engineering Services	15	..	..
Other R & D	18	22	58
	==	==	==
Percent of Total	40	40	20

development in all areas. The percentages we have projected may deviate as much as 10 or 15 percent depending on the accuracy of our planning. We will program our funds to obtain a maximum amount of technological progress toward our target. The cost of hardware, particularly in those years we award contracts for major plant components, will cause the annual rate of expenditure to vary considerably. We do not know at this time when the funding will peak.

The intermediate range program is designed primarily to produce information which will be required for plant construction during the period 1972 to 1975. If you remember the previous chart, this means water down to 25 cents a thousand in large installations.

This phase of the program may produce some information which can be used to meet short-term requirements, but the major benefits from this effort will be applicable to the period 1970 to 1975.

The long-term program consists primarily of basic research in those areas where little is known today, but show promise. No immediate benefit is anticipated from this phase of the program, but the information produced from these studies will advance today's technology and produce tangible results after 1975.

The construction of a 50-million gallon per day plant will provide us a scale-up of desalting plant equivalent to that of a Dresden or Yankee atomic powerplant. We believe that such an installation will provide a dramatic reduction in the cost of producing fresh water from the sea. Just as the Dresden and the Yankee atomic plants pioneered in bringing atomic power costs down to a level which has made atomic reactors economically attractive to the power industry in many areas of the country, so also may one or two multimillion gallons per day plants establish the economic practicality of desalting water. Our national experience with even fossil fuel burning equipment is an incentive to move into large plant studies and design.

The economic effect of scale-up in desalination equipment, as correctly stated by both previous witnesses, will not be the same as for scale-up of both powerplant and reactor economics. I think desalination will move slower, but we will gain many benefits from large-size plants.

Our proposed first generation large-scale plant will use a distillation process, but the specific type of distillation cycle has not yet been set. At the moment, the odds are that this plant would employ multistage flash or multistage multiple-effect equipment; however, these odds could change in the ensuing weeks and it may be that LTV equipment, which is the process used in the Freeport plant, will be employed.

As one of the steps leading to the construction of the prototype plant we have awarded conceptual design contracts to 15 of the best manufacturing and architect-engineering firms in the United States. Through these contracts we are marshaling the creativity and capabilities of American industry toward the goal of economic conversion of large quantities of water from the sea. The utilization of large-size plants as a cost-reducing phenomenon has not only served the development of atomic energy but it has also been demonstrated over and over again in the power and chemical industry.

The desalting demonstration plant built at San Diego, Calif., was operated for just 2 years. During that relatively short period of time, we gained a substantial amount of valuable operating data. The plant provided us with our only opportunity to date to operate a 1-million-gallon-per-day multistage flash distillation plant. I doubt if a hundred paper studies could have provided us with the solid data we were able to obtain from our experience with that plant. Improved operating techniques, including better scale control methods, permitted us to increase operating temperatures which in turn increased plant productivity by 40 percent.

All of the new information we developed during the operating period has been carefully evaluated and analyzed to provide the basis for the advanced design of San Diego II which we propose to build as a replacement for the original plant.

Plans are moving rapidly ahead for the establishment of a West Coast test center where the necessary preliminary engineering developments based on the conceptual studies, the San Diego II experience and inputs from our research and development programs must be accomplished before we will propose the design and construction of a large plant. This work will include the construction and operation of modules of the full-size plant to economically develop accurate information on hydraulics, heat balance, scale control, and so forth and identify the parameters most influential on cost and performance such as temperature, flow rate, blow down, concentration factors, and so forth.

The information thus obtained will be used as a reliable basis for the design of the 50-million-gallon-per-day plant. Models of other necessary equipment or of other processes may also be constructed. We intend to test only those processes which can be effectively scaled up or down for economic gain. The chronological development and construction of large distillation plants is outlined on chart F.

This is a very important chart for the simple reason that it shows a balanced program of engineering development. It shows we are not only planning a plant of 150 million gallons per day or larger, which will be dual purpose, but it also shows we have programs leading to the 10- to 20-million-a-day size for single-purpose and 10 to 20 million for dual purpose and going to second generation 3- to 5-million-gallons-a-day single-purpose plants. All of these lead to the 50- and then the 150-million gallon or larger dual-purpose plant, some time in early 1972. At the same time, we plan to develop the hardware for the 40-million-gallon single-purpose plant, which could also be dual purpose. What we are trying to do is develop a family of plants without overemphasizing large plants. We know we need plants to produce 10 million or 20 million gallons of fresh water per day. In fact, we know there are more plants of that size needed than the 50 million or larger.

As the 50-million-gallons-per-day plant may in fact be a module of still larger plants, we need data for the determination of optimum engineering technological parameters, the optimum modular size, the maximum size of a single hydraulic system, and the achievable economic gain as a function of size and maximum operating temperature.

When this type of information has been established, we then have the opportunity to back off to the most economic and reliable operating conditions. For example, we will reach a point in operating temperatures where steam pressures will require stronger and more costly hardware, but the upper limits must be established so that we can determine the engineering tradeoffs we need to make for optimum economy.

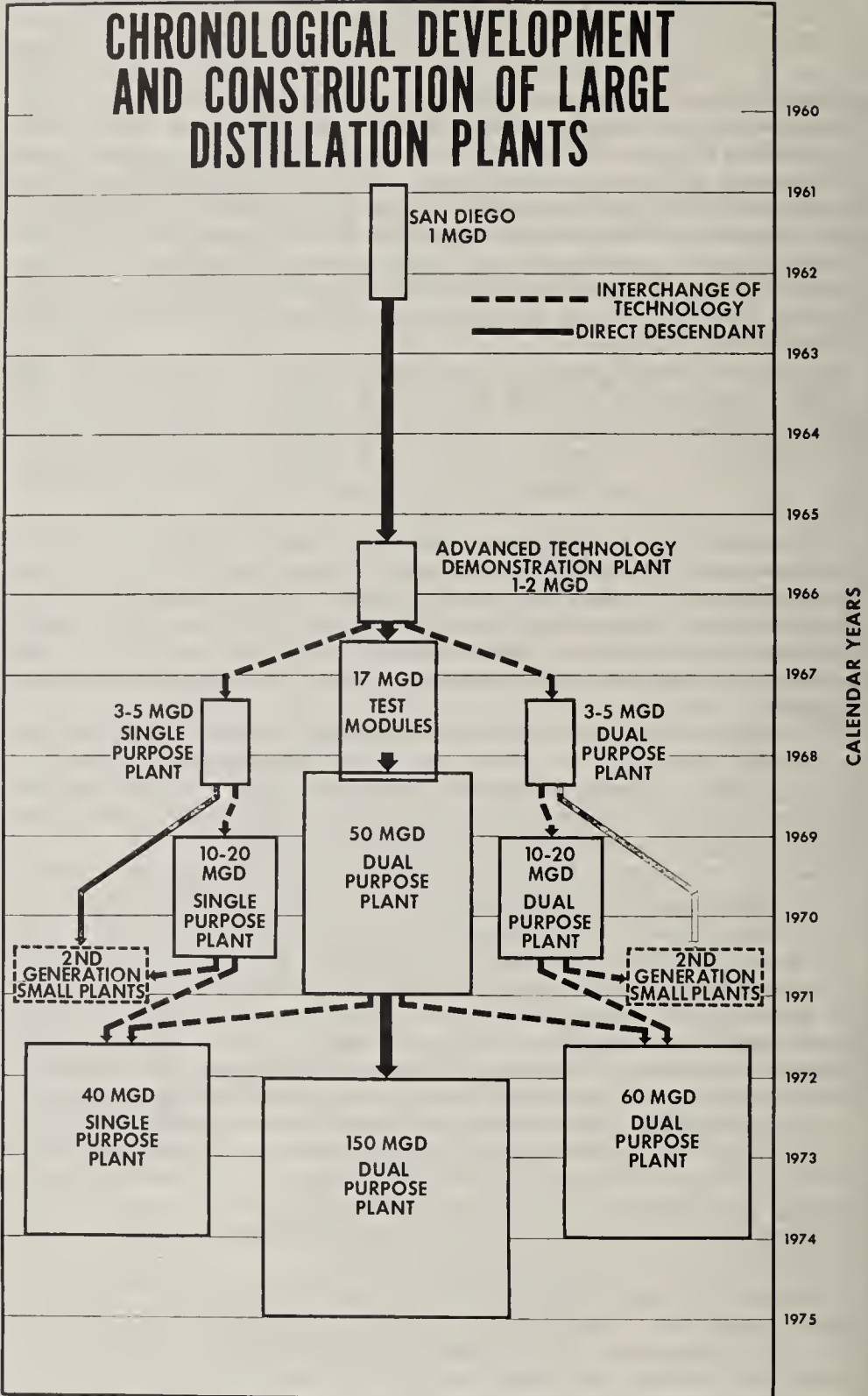
The Office of Saline Water will not propose to build a 50-million-gallon-per-day plant simply to prove out quantity production and wind up with a white elephant. Our sole interest in a large dual-purpose plant will be to demonstrate the achievement of the lowest price water possible through use of the best available technology.

We are not fascinated by the 150 million gallons of product water; we are fascinated by the 150 million plus the price per thousand. It is the second factor that is going to make our study worthwhile.

It is our belief that the status of engineering development needed to support the construction of a 50-million-gallon-per-day plant has not attained an appropriate level unless one is willing to take unreasonable technological and economic risks. Optimistically today's status of engineering development technology might support the construction of two 25-million-gallon-per-day units, or possibly three 17½ million gallon-per-day sections, or more realistically, five 10-million gallon-per-day plants. Any of these configurations would certainly provide cheaper desalted water than can be produced by an existing plant, but at this point in time we believe that one optimized and properly sized module, as we have targeted for the program, will be better both technically and economically.

To meet our responsibility to the Congress and in turn to the taxpayer, we believe it would be unwise for us or anyone else to proceed with the construction of a large plant until we have collected and drained all usable data from the available technology and refined it to a point that we can move forward with the assurance that the plant

CHART F



CHRONOLOGICAL DEVELOPMENT AND CONSTRUCTION OF LARGE DISTILLATION PLANTS

Chart F depicts the programed stepwise engineering developments leading to the construction of large-scale desalting plants.

The original San Diego 1-million-gallons-per-day plant provided solutions to many problems, including (a) those encountered in higher temperature operation (up to 250° F.) with acid treatment to prevent scale formation, and (b) those involving control of brine level and ways to maintain equal distribution of vapor flashing in a large number of evaporator stages. The plant also provided operating experience in the areas of corrosion control and maintenance requirements.

Development work will continue through the time period indicated on the chart. This involves a logical progression of experience and technology through an advanced technology demonstration plant of 1- to 2-million-gallons-per-day capacity; a module test program; a 50-million-gallons-per-day prototype plant; and finally a 150-million-gallons-per-day plant.

The advanced technology demonstration plant is a follow-on plant to push multistage flash technology considerably beyond that obtained in the old San Diego plant. It will provide operating data on a practical scale with higher temperatures and pressures (350° F. versus 250° F.); twice the efficiencies, 66 stages and 2-to-1 performance ratio in contrast to 36 stages and 10-to-1 performance ratio for the old plant; a sizable reduction in overall stage dimensions; and more sophisticated instrumentation.

One or more large test modules will be built, based on experience gained from the advanced technology demonstration plant and the conceptual design studies now being prepared under contract for OSW. Modules consisting of an integrated arrangement of full-size components, such as pumps and flash stages, will be built and operated to insure satisfactory performance before committing ourselves to an expensive prototype plant. The 50-million-gallons-per-day prototype plant is expected to be a production plant incorporating the best features of technology derived from the demonstration plant and test module.

Much of the experience and technology obtained from the central development program will be advantageously used in concurrent design and construction of smaller plants in the range of 3- to 20-million gallons-per-day, single- or dual-purpose plants, thus providing a balance to the program which will develop desalting processes to meet a variety of size requirements.

we are building represents the most advanced extension of the art within the bounds of sound engineering extrapolation.

Through the work we plan to perform at the proposed west coast test site, we expect to gain much of these refined data requirements. At the same time, results from the operation of smaller units, including the information we will obtain from the facility we will build as a replacement for the plant transferred from Point Loma for use by the Navy at Guantanamo, as well as feed in from other research and development activities and the conceptual design contract studies, will combine to put us in a position to move with a reasonable degree of assurance that the 50-million-gallon-per-day or larger prototype project will be successful.

If the focus of need and national attention had been directed to a 50-million-gallon-per-day plant 5 years ago, then progress toward its accomplishment could have collapsed the time schedule; but even so, we may not have been able to move with any greater speed than we are now planning as the schedule would perhaps have been delayed because of lack of public confidence that it could be achieved. At best, a year or so may have been saved.

Our estimates indicate that 14 years for a relaxed program to design and construct a large desalting plant would not be unrealistic. We will present data on the chronological development of various processes and the promises made and unkept. That timetable through good engineering administration and attention to detail and high-priority assignments can be cut in half, but we would still require 5 to 7 years to develop, build, and place on stream a large plant.

That program we are asking the Congress to authorize may give us a large operating plant in 5 to 7 years. A project of this magnitude must be considered in the light of the availability of resources, both material and human, which will be required for its accomplishment.

This proposed program has been carefully worked out with the assistance and counsel of the Office of Science and Technology and through conferences with the Atomic Energy Commission and with the advice of private industry and individual members of the scientific and engineering community and the review groups I mentioned earlier. Even with this extensive program planning, I would be less than honest if I did not frankly state that there are yet many unresolved questions.

There are some who believe that the distillation process is ready for utilization now in plants of 50-million-gallon-per-day capacity or greater. This committee has received statements to that effect at this hearing. I do not intend to dispute their position; in fact, we are delighted to know that some industrial firms have decided that they are capable of providing an installation of that size. I would like, however, to add this thought, which I hope is not construed to be pessimistic, but rather a word of caution.

The jump from present 1-million-gallon-per-day plants to the 50-million-gallon-per-day size or larger is not beyond the realm of engineering feasibility. Certainly, the turnkey construction of such a plant can be guaranteed, but more important than its construction is the question of what will be the capital investment and cost of water produced in alternative plant designs unless we develop other processes and industrial competence? In all frankness, one must ask: Where did these companies gain the expertise through which they propose

to build and warrant some of the characteristics of a plant of this size? Without question much of it is a direct result of information they have gained through participation in the Department of Interior's saline water conversion program, specifically the San Diego and Freeport plants.

I do not mean to cast any kind of cloud on Fluor or Westinghouse; they are both extremely competent contractors and we are glad to have them in our program. But it is most interesting to note that the two contractors who designed and built the Point Loma plant are the two contractors that have the greatest confidence that they can now build a large plant. I think it is just more than pure coincidence.

If at some location, either in the United States or abroad, there exists an immediate need for such a plant and the cost of the product water is not an overriding consideration, we are confident that a plant of this size, based on the San Diego or Freeport design, can be built. It would, however, be a first-generation plant, it will certainly have problems that must be corrected.

There was a question came up yesterday when Mr. Simpson was testifying about whether the Office of Saline Water had made any contribution of technical value to Westinghouse. He replied, no, they had all the inhouse capability; in fact, the Point Loma operation was by then built and nothing else had helped them. I think he now realizes that this is not quite correct. Factually, the parameters established for the design of the plant were developed by the Office of Saline Water. They listed all the critical factors that had to be designed in the system. Westinghouse, on the basis of this information, did develop the design of the deaerator, and they did develop the arrangement of steam-condensed design. They also worked on the flow control between stages, which was later improved; they developed the recycle flow design, designed the entrainment separator, and the fixed-gas removal system; developed tube seals through stage partitions and improved the design of the recycle pump. These are areas where Westinghouse contributed but so did Fluor and others. Fluor contracted equipment suppliers and other engineers to obtain ideas from all sources.

OSW awarded the operating contract for the San Diego plant to Burns & Roe, Inc. They made four substantial changes: they developed the pH method of scale control, improved the flow control of recycle brine, improved the removal of fixed gases, and increased the temperature range of operation from 200° F. to 250° F.

The combination of all these things resulted in a plant which produced a maximum of 1.4 million gallons per day as against the 1 million gallons it was designed to produce, and it operated steadily at one and a quarter million gallons per day. The only reason I am endeavoring to correct the record is because I am sure Mr. Simpson himself would not like to leave the impression that research in which his company is actively participating—we currently have four contracts with Westinghouse—was of no benefit to them. I am not trying to deemphasize the value of Westinghouse's work, they have made real contributions.

Our role certainly is not to create a monopoly for a few companies, who through their activity in this field to date may find that they have a competitive advantage. Only a few of the potential processes

have reached any degree of refinement, and the demand for water is such that it will be absolutely necessary to create a range of processes to meet a variety of conditions. The process that best meets the need of a small community to desalt brackish water will not be the process that economically produces millions of gallons of fresh water per day from the ocean.

This may not turn out to be an act of prophesy. Some process may come along which will handle all types of saline water, but such a process is not in sight at this time.

Factors which will affect the performance capabilities of processes include not only the type and salinity of the water to be desalted, but also the purity requirement of the product, the size of the plant, the cost of fuel, the temperature of the raw feed water, whether it is the sole source of supply or incremental supply, single or dual purpose. Some processes may be adaptable to meet a variety of these conditions, but it is highly unlikely that a process will be developed to best meet them all; thus we foresee a need for a family of processes for a variety of applications, each tailored and developed to better economically answer a specific water supply situation.

There are a number of methods through which saline water can be desalted—some of them have been known for centuries, some are fairly recent, some are new—but none have yet reached their full economic potential. It has been easy to predict low-cost desalted water, but to produce it is something else. The chronology of development of several processes has followed a reasonable engineering pattern, but actual progress has never quite been able to meet optimistic economic projections.

Electrodialysis, as a laboratory phenomena, has long been known; but it was not until 1950 that the first practical permselective membranes were produced. Between 1950 and 1952 laboratory experiments were conducted on membranes and the first bench size experimental unit, with a capacity of 2,400 gallons per day, was constructed between 1952 and 1954. At this early stage of the development of the process, its advocates were confidently estimating product water costs of 6 to 12 cents per thousand gallons. Development work continued between 1954 and 1961, and while a number of improvements were achieved, a greater number of problem areas were discovered including the adverse effect of suspended matter on the membranes, membrane scaling and deterioration, polarization, the deleterious effects of iron in water, electrode deterioration, and spacer instability.

During this period of progress, a 25,000-gallon-per-day pilot plant was being field tested and estimates of product water cost by using electrodialysis to desalt sea water were completely eliminated from economic projections and the cost of demineralizing mildly brackish water rose to a more realistic 60 to 80 cents per thousand gallons. Electrodialysis could get the brackish water up to a certain parts per million, but the economics just did not seem to be good to try it on sea water. During 1962 and 1963, the Office of Saline Water constructed a 250,000-gallon-per-day electrodialysis brackish water conversion plant at Webster, S. Dak. In its first year of operation, the actual cost of water from this plant was \$1.18 per thousand gallons. Now, through engineering developments and advances in operating techniques, the cost curve is coming down and a cost of less than \$1 per thousand gallons is in sight.

Again, something which has been quoted too many times to let stand, is the performance of electrodialysis at Buckeye, Ariz. Again, the key to efficient operation of an electrodialysis plant is the chemical analysis of the water. The water at Buckeye is a much simpler water than they have at Webster and Roswell. Roswell is probably the worst water we have ever run into.

A new membrane process—reverse osmosis—is just now reaching the pilot plant stage of development. Although much development work still must be conducted before it is ready for practical application, results obtained thus far indicate the process has good potential for desalting both sea and brackish water.

The technology for crystallization processes, including freezing and hydrates, has been partly developed in the laboratory and pilot plants have been effectively operated on freezing processes. If the potential advantages for freezing processes continue as real possibilities for accomplishment after further development, then test bed plants up to 1 million-gallon-per-day capacity can be justified within the next 3 years. The hydrate processes are just now entering the small pilot plant operational phase, and it is expected that their development will proceed in a comparable manner.

The technology of the use of ion exchange in water softening and water demineralizing has been well developed over many years and has wide commercial application. The salinity limits of the waters which ion exchange processes could economically treat have been very low—in the several hundred parts per million total dissolved solids range. However, very recent developments making use of newly developed ion exchange resins, together with new approaches to regeneration of the resins, may make ion exchange desalination less costly than electrodialysis when applied to waters up to 3,000 parts per million. Thus, plans for a test bed plant in a 500,000-gallon-per-day capacity range should be justifiable within the next several years.

Aside from the technical aspects of the program, we must, at least in a preliminary way, analyze the water supply situation. It is obvious that the principal customer for desalting plants will, in all probability, be a political subdivision of government. Thus, we plan to do more in this area; such as, identifying areas of water needs, conveyance costs, alternative water sources such as surface, subsurface, and reclaimed waste water, within and outside of the area under study, and the related economics. This will be done in concert with other bureaus of the Department of the Interior and other Government agencies. There will, of course, be instances where private water companies or an industrial firm will purchase a conversion plant.

Of great importance also, American industry will find itself in the marketplace in competition with foreign interests. A measure of foreign interest in the desalting program can be drawn from the response to the invitation that has been extended to governments to send official delegations to the International Symposium on Water Desalination to be held here in Washington next October. Fifty-two nations have already advised us that they will be represented, and more are expected.

The last thing we will want to happen is for our technology to fail to meet commitments to either our own public customers or foreign countries. Saline water conversion plants will, in my opinion, become

an important part of U.S. foreign policy, and the work we do to sharpen technology to its most effective point will help raise to greater esteem our national prestige in the family of nations, especially in those countries where the thirst for water is already critical. It would be my hope that every time a human being in a foreign land swallows a mouthful of fresh water obtained from a plant based on U.S. technology he would savor the genius and humanitarian generosity of this great Nation.

President Johnson stated his aspirations for the desalting program in the letter which transmitted for the consideration of the Congress the legislation that is the subject of this hearing today when he wrote:

By pressing ahead with a vigorous program of economic desalting to meet our ever-growing needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage.

Senator ANDERSON. Thank you, Mr. Di Luzio. Do you want these charts to appear in the record?

Mr. DI LUZIO. Yes, sir. I would also like to include a description of our engineering development test facilities.

Senator ANDERSON. It is so ordered.

(The data referred to follow:)

ENGINEERING DEVELOPMENT TEST FACILITIES

PILOT PLANT TEST FACILITY

Present engineering development activities of the Office of Saline Water for process development are located at Wrightsville Beach, N.C., in a test facility where various new conversion processes can be operated at the pilot plant level under controlled standardized conditions.

The facility provides the Government a site for a pilot plant testing and an east coast conversion plant. This property is ideally suited for the requirements of sea water conversion applied research and engineering development activities.

There is an available source of clean sea water; the area is protected from storms; U.S. highways border the property, thus providing excellent accessibility; there are no building restrictions; and brine disposal has not been a problem. The research and development test station, including the east coast conversion plant now occupy about 13 of the 25 acres.

This site is about one-half mile from the shore. The station has nine pilot plant plots, a skimmer pond, aeration basin, and impounding basin for waste disposal, office building and laboratory, a corrosion test building, maintenance shop, garage, utility building (boiler house), and fuel storage facilities. In addition to the 9 original pilot plant plots, 2 additional plots have been constructed and a third is scheduled, providing for a total of 12 test sites, the smallest being 22 by 32 feet and the largest 102 by 32 feet. The concrete slabs are 18 inches thick, supported on wood piles and are various sizes. All pilot plant plots are exposed except for plot No. 1, which is enclosed in a steel frame asbestos siding building and which houses a pilot plant that requires protection from the weather.

Utilities supplied to the pilot plant area are:

High-pressure steam (30,000 pounds per hour total capability with space for an additional 30,000 pounds per hour).

Low-pressure steam.

Compressed air.

Sea water.

Fresh water.

LP gas.

Electrical (2,000-kilovolt-ampere maximum).

Waste brine is discharged into a drainage system from all pilot plants except those in which hydrocarbons are used. Pilot plants which use hydrocarbons in the process are located in what has been designated as a hazardous area. This area is separated from the rest of the station by a 75-foot safety zone and all wastes from these plants are directed to a skimmer pond, aeration basin, and impounding basin. The wastes from both the impounding basin and the main pilot plant area are then released into Wrightsville Sound.

The sea intake pumps are located approximately one-half mile east of the test station property in Banks Channel. A concrete pier in the channel supports three 1,600 gallons per minute ventical turbine pumps and a control house. With all three pumps operating, approximately 7 million gallons of sea water per day can be supplied.

The research and development test station permits OSW to centralize its pilot plant operations in one location. This concentrated effort results in more effective use of manpower and funds and produces comparative information, since all experimental units and pilot plants operated under similar conditions using the same sea water.

The following pilot plants have either been erected and operated or are scheduled for construction at the test station :

37,000 gallons per day distillation thin film.

20,000 gallons per day hydrate.

15,000 gallons per day direct contact freezing.

10,000 gallons per day descaling and product recovery.

2,000 gallons per day falling-film scale control.

200,000 gallons per day east coast conversion plant direct contact freezing.

7,000 gallons per day distillation thin film (marine unit).

10,000 gallons per day flash-distillation scale control.

60,000 gallons per day vacuum freezing.

25,000 gallons per day distillation flash-evaporation scale control.

10,000 gallons per day distillation thin film (marine unit).

3,000 gallons per day distillation horizontal spray thin film.

As the overall OSW program is expanded, the pilot plant operations at this station will continue to expand.

In anticipation of additional space and facility requirements, specifications for additional facilities are being prepared. A construction contract for approximately \$200,000 is anticipated in the 1966 program. The work will include construction of a warehouse, locker facilities, and office additions, an underground drainage system, water storage, safety alarm system, paving, and miscellaneous modifications.

The Wrightsville Beach Test Station has become a most important facility in the OSW program of saline water conversion. Space is available for future expansion; however, utilities will need to be expanded to serve the additional areas.

BRACKISH WATER TEST FACILITY

The OSW demonstration plant program has included two different processes on brackish water, one at Roswell, N. Mex., and one at Webster, S. Dak. In both cases, in the operation of the plants and development of the distillation and electrodialysis processes, large problem areas have developed due to the presence of certain impurities in the water. There is a definite need for specific research and engineering testing to overcome these problems. Certain of the processes, such as reverse osmosis and freezing, may be more profitably used on brackish water; however, research and engineering testing facilities are needed to effectively develop processes for this type of water.

The inland water sources contain naturally occurring impurities and, in addition, there are other mineralized or chemically charged waters from municipal or industrial sources. Impurities not present in ocean water but of significant interest are such items as silica, sulphate, sulphite, sulphide, phosphates, detergents, and other organic chemicals. There will also be certain heavy metal chemicals such as iron and copper present in some of these waters.

There is a need for a test facility to handle brackish waters in which processes up to 50,000 gallons per day can be evaluated. Such a facility would of course use natural waters obtained from wells and surface streams but would also need to have mixing facilities to prepare synthetic waters equivalent to those found throughout the arid brackish water zones of the United States.

COMPONENT TEST BED FACILITY

The development of sea and brackish water conversion processes follows in a sequence of work: research, bench scale testing, pilot plant testing, and test bed development. From the pilot plant comes a process which will produce the product and much technical data for design of operating plants. Usually there are certain features of the process equipment that are not fully explored. Examples of such features may be pumps, valves, instrumentation, vessel shape and dimensions, and materials of construction.

For the most economical arrangement of equipment for any plant, each component must be designed to fit harmoniously with the others. Much of this design work can be done by competent engineers who specialize in the various unit operations involved. The testing of those components which are of a design, size or shape not available commercially need to be tested. The construction of a component test bed facility is planned for in the 1966 budget.

It is expected that a site can be arranged for near an existing power-generating station, where steam and electric power can be purchased at a favorable price and at flow rates required. Energy requirements for some of the components may be relatively high. Water, steam, and electric power needs are expected to be some 5 to 10 times greater than is available at the pilot plant test facility.

The physical requirements for the test bed facility have been estimated to be:

Steam at 50 pounds per square inch gage: 600,000 pounds per hour.

Electric power: 12,000 kilowatts.

Sea water: 70,000 gallons per minute.

Waste water: 70,000 gallons per minute.

Size of site: 20 acres.

Senator ANDERSON. You mentioned the fact that you would ask your associates to make some statements. Would it be satisfactory to have those merely inserted in the record at this point?

Mr. DI LUZIO. Yes, sir.

Senator ANDERSON. We are very pleased to have had you before this committee.

The statements of your associates will be placed in the record at this point.

(The statements referred to follow:)

STATEMENT OF DR. W. SHERMAN GILLAM, ASSISTANT DIRECTOR FOR RESEARCH AND DEVELOPMENT, OFFICE OF SALINE WATER

I. INTRODUCTION

Under the impetus of the Anderson-Aspinall Act a dynamic research and development effort has been established with its objective directed toward the attainment of low-cost fresh water from the sea and other saline water sources. This research program was established only after detailed and exhaustive studies were made on desalination and the water problem. (One such study was that sponsored by the National Academy of Sciences-National Research Council in 1961—NAS-NRC Publication 941.) Scientific disciplines requiring research support were detailed, and gaps in our knowledge were delineated by that study. Based on those results a well-planned, balanced, research program was laid out in great detail. Results from such a young program have been excellent and an even more productive effort is anticipated under the proposed program.

The proposed research and development program has been based on: (a) the experience and knowledge attained during the past 3½ years; (b) needed new research to fill existing gaps in knowledge; (c) the requirement to develop specific data and give the maximum support feasible to distillation and membrane processes; (d) current research projects, estimated contract renewals, and research proposals in hand; (e) the need for new concepts, ideas, and inventions; and (f) the availability of highly qualified competent scientists and engineers who have been attracted to the challenging problem of desalination.

The research activity embraces not only basic and applied research but also some development. The program supports projects in most all relevant areas of science and engineering, including investigations on byproducts; and stresses publication and coordination of pertinent scientific data. A considerable effort

is being devoted to a better understanding of the kinetics and mechanisms by which heat, water molecules and ions are transported to and across boundaries so that these basic steps (which are inherent and vital to any separation process), can be made fast and efficient. Fundamental principles, new concepts and the attainment of new knowledge that is generally applicable to any process of saline water conversion are also emphasized in the program.

The basic research effort has relatively long-range objectives and is the area in which the ultimate solution to the conversion problem eventually will be found.

Before detailing specifics of the proposed research program, the unique nature of the problem should be pointed out and a realistic appraisal given as to the opportunity for research and development to yield significant progress.

The problem is unique because of the value of the product. Currently a load of dirt delivered to your residence will cost about \$5 per cubic yard, or, using water volume units, about \$25 per 1,000 gallons. Our current demonstration plants produce water for about \$1 per 1,000 gallons. So if we are successful in producing water "cheap as dirt," we are not even in the ball park in terms of achieving our objectives. Another perspective is to consider that 1,000 gallons of water is over 4 tons of product, which by current technology requires processing perhaps 10 tons of material. Processing technology today is based on a product having an economic value of at least a penny a pound. Processing techniques and equipment have evolved on this premise, or, perhaps more accurately, where this premise is not valid, processing techniques have not evolved. Product water at 100 pounds per penny is equivalent to 83 cents per 1,000 gallons, still far more than people want to pay. In desalting, it is necessary to process a ton of product, and probably twice that amount of raw materials, for a nickel, or less. This will certainly demand the highest possible degree of ingenuity and inventiveness if it is to be achieved.

Can it be achieved? Is it even realistic to hope for success? Can research lead to practical methods of desalting sea water. The answers to all of these questions it is believed are affirmative. Desalting is a particularly opportune field for research at this time for the very reason that present processes do not approach theoretical efficiency. Whereas one could, at best, hope to increase the efficiency of an electric motor by a few percent through additional research, there is very real opportunity to increase the efficiency of water desalting by a factor of five or more. The way to attain major improvement in product cost is by research on the principal sources of irreversibilities (inefficiencies). For most desalting processes, these irreversibilities arise largely from transport of energy or matter at phase boundaries. Nearly all of the present processes require more than 30 times the work energy needed for reversible separation. Several can use the work available from low-temperature energy, which is seldom useful for other purposes. Existing methods employ semipermeable membranes or interfaces between phases (liquid-vapor, liquid-solid, or liquid-liquid). Most of these are rapid but thermodynamically quite inefficient; reverse osmosis is efficient but slow.

Basic research will provide a better understanding of both the transport processes and the thermodynamic losses. Hence, research has an opportunity and potential of truly unusual dimensions for achieving dramatic reductions in the cost of desalting water. This research activity is centered on the structures and properties of the substances involved (such as water, aqueous solutions, hydrates, membranes), and the fundamental processes (for instance transfer of mass, momentum, heat, electricity) which may offer the possibility of separating water and ions.

II. PROPOSED PROGRAM

The proposed program will increase support in those areas of the physical sciences where research can be expected to contribute to the solution of saline water conversion problems.

The scope is necessarily broad and encompasses the following areas:

1. Structures, including the structure of liquids and solutions; of ice, hydrates, and clathrates; and within membranes and ion-exchange resins. New basic information in these areas would remove much of the empiricism that characterizes the attempts to improve existing desalination processes and to devise new ones.

2. Thermodynamic properties of binary and multicomponent aqueous solutions; of solution surfaces; scale-forming reactions and membrane processes;

and of saline water, sea water, and concentrated brine, both natural and synthetic. Notably lacking at present is information at high temperatures, pressures, and concentrations.

3. Transport phenomena, properties, and theories. Especially needed is information concerning the passage of both matter and energy across phase boundaries, in and through membranes, and at electrodes. Since all separation processes, existing or to be invented, of necessity involve movement of either water or dissolved constituents, all aspects of material and energy transport are important.

4. Membranes, an essential part of several existing and proposed separation processes, are poorly understood with regard to the interrelation of methods of preparation, structure, and properties. Much of our meager knowledge concerning mechanism of transport, ionic selectivity, and salt rejection of membranes requires a much firmer theoretical basis as well as added empirical information.

5. Materials of construction for desalting plants are necessarily a major factor in determining the cost of product water. Cheaper and/or longer-lasting metals and alloys, plastics, coatings, and sealants, cements and concretes, heat transfer media, polymers, etc., will contribute to cheaper water from present and future processes.

6. Brackish waters represent the only feasible new source of water for many arid regions of this country and the world. Unlike sea water, brackish waters differ in quality, quantity, and composition not only from place to place, but also from time to time even at a given location. The program to date has necessarily been limited to general methods with no more than cursory consideration to variations in water composition. Because brackish waters are less saline than sea water, they are economically more attractive than sea water, and the special considerations necessary for their utilization must be recognized and dealt with.

7. Biology appears as a field that, in the past, has contributed little to desalination, but one that may now provide much information useful directly in desalination, as well as in other aspects of the total water problem. Living membranes carry on desalination operations with a high degree of efficiency. A better understanding of the mechanisms of these processes has obvious connections with the design and use of inanimate analogs.

8. Unconventional desalination ideas may provide a hint as to the possible areas in which "breakthroughs" might occur. The optimum separation probably has not yet been thought of and new ideas or little understood phenomena that appear relevant to desalination will be investigated. Unconventional methods of heating in conventional distillation processes may provide the means of eliminating costly scale formation.

The above broad areas of research point out the great diversity of problems and the intertwining of causes and effects associated with saline water conversion. A general objective of the research program is to attract the best possible talent to the problems of desalting, with new ideas, new concepts, and new inventions that will indeed break the economic barrier to universally cheap, potable water. The following sections briefly outline the recommendations for research effort in fields of particular interest, promise, or relevance to the saline water conversion program.

New concepts

It is probable that the ultimate answer lies in a yet-to-be-discovered process. Present methods of desalination have centered on known processes, such as distillation and freezing, which requires a phase transformation of liquid water to the gaseous or solid states. To effect these phase changes requires the expenditure of energy, which energy can be partially recovered when gaseous steam condenses, or ice melts, to reform liquid water. The efficiency of this energy recovery can be increased by judicious engineering design, but this necessarily entails increased capital costs, so that present plants are optimized in terms of current technology to give minimum cost water by making the best possible "trade-off" of capital costs and energy consumption.

As the technology of these processes advances, it will be possible to effect substantial savings by operating at conditions which were previously not optimum for reasons which new developments have made invalid. The prevention of scale, or more efficient heat transfer, or heat transfer by other than metallic surfaces (e.g. liquid-liquid transfer), or elimination of corrosion, for example, could effect

substantial savings in any distillation process. Efforts to achieve these goals will be intensified as the OSW program expands. Economic recovery of by-product(s) from sea or saline waters would aid in reducing water costs, and could afford a new source of an important raw material in its own right. Methods of operation which yield a more concentrated reject stream not only increase the water yield, but also give a brine which is more attractive for recovery of byproduct mineral values. Future efforts must be directed toward creating a technology which permits higher concentration ratios, as well as the recovery of mineral values from these brines.

As we look at the future of desalination, however, it is apparent that a process which does not require a phase change will have a great inherent advantage over those processes which do (as distillation and freezing). Reverse osmosis is an example of such a process which has undergone rapid development in the OSW program in recent years. This is the process of expressing pure water through a semipermeable membrane by application of a hydrostatic pressure to a saline solution. If the hydrostatic pressure is greater than the osmotic pressure of the solution, the net water flux will be such that pure water is obtained from the saline solution. An inherent limitation of reverse osmosis, however, is that as water flows to the membrane surface, it carries dissolved salt with it, thereby increasing the salinity of the boundary layer immediately adjacent to the interface. The boundary layer of increased salt concentration has proportionately larger osmotic pressure. This results in a decreased water flux through the membrane at a given hydrostatic pressure. Also, as the salt flux through the membrane is proportional to the salt concentration at the membrane surface, decreased salt rejection is experienced. Overcoming this boundary layer effect, or "concentration polarization," is one of the most important problems bearing on the future of reverse osmosis.

One approach to this problem which, incidentally has been successfully perfected by nature in life processes through millions of years of evolution, is utilization of thin channels having dimensions smaller than the boundary layer which ordinarily would be built up. The design problems of successfully applying this solution are extremely formidable, but this and other innovations (turbulence promotion, pulsing, etc.) and design concepts (vertical spiral, shell and tube, plate and frame, thin channel, etc.) must be tested, evaluated, and brought to fruition.

Recent research results have been extremely encouraging and considerable progress has been made in understanding the fundamental principle of reverse osmosis. Equations of flow have been developed, boundary layer limitations are better understood, membrane casting techniques have been improved, and theories have been advanced to explain the role of special salts in membrane fabrication. Theories have been advanced to explain the mechanism of water transport and salt rejection, and some of the physical and chemical characteristics which impart unique properties to cellulose acetate membranes have been elucidated. Whereas the early membranes had a water flux of 0.2 gal./sq.ft./day, membranes have been developed under the current program which have water fluxes as high as 22 gal./sq.ft./day, an increase of more than a hundredfold. A pilot plant with a design capacity of 1,000 gallons per day has been fabricated and operated successfully on sea water. The research work carried on to date has answered many of the outstanding questions about the reverse osmosis process. The results to date also point out that much additional research is required with respect to membrane cost and lifetime. The problem of membrane cost has not been exposed sufficiently, data on the question of lifetime are not entirely self-consistent, and the mechanism of failure is not understood. As a result, research must continue on:

- (1) membrane lifetime and the factors affecting lifetime;
- (2) means of improving cellulose acetate membranes and means of changing the operating conditions so that the lifetimes can be extended; and
- (3) the search for alternative materials which combine suitable permeation properties with greater durability.

In addition, new research effort will be devoted to the problems of membrane production on a commercial scale. Promising leads to ways and means of developing membranes showing properties superior to cellulose acetate have been uncovered in the basic research program. A breakthrough in membrane technology could occur at any time and an expanded membrane research program will increase the probability of the event's occurring in a shorter period of time. Since the membrane is the key to the success or failure of the reverse

osmosis process, the membrane research program requires primary emphasis at the present state of reverse osmosis technology.

Looking beyond reverse osmosis, the research program must seek new methods and new concepts of separation which do not require a phase change, which do not involve boundary layer phenomena, and which separate salt from water, rather than water from salt. Electrochemical desalination is one such method, which, compared to other processes, has inherent cost and cycling advantages that are particularly pronounced with respect to brackish waters. Most desalting processes require expenditure of work (thermal cycling in distillation and freezing, mechanical work in reverse osmosis) on the total liquid volume in order to recover only a fraction of the total water. A 3,234-parts-per-million brackish water has 1 salt molecule for each 1,000 water molecules. The inherent advantages of removing the salt from the water (rather than vice versa) are obvious. Thus far, work has centered on the use of carbon electrodes for reasons of (1) economy, (2) ease of chemical modification, (3) total available surface area, and (4) the fact that it is electrically conductive. If the inherent advantages are to be realized in fact, it is apparent that an intensified effort will be necessary to increase current efficiency, increase electrode capacity for ion adsorption, increase rate of ion adsorption, etc.

The proposed research activity will encourage additional programs of an exploratory nature, placing a high premium on inventiveness, which are not subject to one or more of the inherent limitations of existing processes, and are therefore, deemed particularly apropos to the development of a technology which could result in a breakthrough in the economics of desalting water. These programs will seek a process which will remove salt, rather than water, from saline solutions; will operate without a phase change, in the absence of any boundary layers, and at essentially ambient temperatures and pressures. In this way the minimum thermodynamic energy requirement for separation of salt and water will be approached.

Fundamental knowledge

Specific areas to be investigated for the development of fundamental knowledge include:

1. Basic studies on the liquid state, water and its solutions:

Theoretical studies on the structure of liquids.

Crystal structure of all forms of ice.

Crystal structure of hydrates and clathrate compounds.

Thermodynamic properties of multi-component aqueous solutions, particularly at high temperature and high concentration.

nonthermodynamic properties including viscosity, diffusion, and conductance of multi-component aqueous solutions.

2. Transport phenomena:

Theory of transport processes.

Transport across interfaces, due to thermal, electrical, concentration, or other potentials.

Mass- and heat-transfer studies with saline waterflow over flat-plates, spheres, and cylinders.

Coupled fluxes in heat and mass transfer.

Transport related to turbulence parameters.

3. Phase transitions, vaporization, crystallization, scale corrosion.

Heat transfer in evaporation.

Condensation coefficients.

Crystallization—rate-controlling steps.

Nucleation.

Kinetics of crystal growth.

The effect of saline waters on metals with respect to composition, structure, and mechanical state of the metal, temperature, composition of solution, oxygen, inhibitors, galvanic effects, and flow conditions.

4. Membranes, ion-exchange materials, and electrochemical processes:

Ion-exchange membranes—interrelation of membrane preparation, structure, and properties.

Ionic selectivity of membranes.

Theoretical and experimental studies of thermodynamic properties and their correlation with irreversible phenomena.

Ion exchange—basic studies on the structure and properties of ion-exchange resins and of water within them, and also the interrelation with properties of ion-exchange membranes.

Use of ion-exchange materials for special desalination processes (scale prevention by removal of scale-forming elements).

Reverse osmosis—mechanism of diffusion of water and other substances in polymers; solubility of salts in swollen polymers, and the relation of this phenomenon to salt rejection.

5. Biological and psychological salt transport processes: Biochemical studies of biological membranes and ion pumps, composite synthetic membranes, cellular basis of salt toleration, physiology and biochemistry of salt rejection.
6. Ion-responsive electrodes: Fundamental investigations of electrode processes and materials.

Improvement of present processes

Although existing processes offer less opportunity for a breakthrough, the opportunity for dollar savings in future plants demands a continuing program for fundamental improvements. For example, a 1 percent increase in throughput of a billion-gallon-per-day plant would represent an incremental increase of 10 million gallons per day, or approximately three times the output of the largest desalination plant in existence today. An aggressive and imaginative program to advance large-scale desalting of sea water will require increased effort in the following areas:

Thermodynamics.—Present desalination plants are designed from data based on the properties of sodium chloride solutions. These data contain errors of a magnitude that do not seriously affect the economics of operating small-scale plants, but which may be quite significant in large-scale plants. An accelerated program of basic research will increase and make available the necessary thermodynamic data of sea and brackish waters in order to arrive at optimum efficiency designs of large-scale desalting plants.

Scale.—The operation of present day evaporators is limited to temperature ranges of 200° to 240° F. Above this temperature range, calcium sulfate precipitates on heat exchange surfaces with resulting inefficiencies at the heat exchanger interface. A more efficient evaporator design might be realized if evaporation took place at higher temperature. It is proposed to investigate the optimum temperature for evaporation and to accelerate the search for scale control methods in order that the optimum temperature of evaporation may be achieved.

Heat exchangers.—The heat exchanger problem cannot be separated from the scale control problem. It is proposed to accelerate the investigation of heat exchanger materials from the viewpoint of higher heat-transfer coefficients, lowered cost, longer lifetime, and scale resistance.

Evaporation phenomenon.—One of the critical limiting factors in any evaporation process is the resistance to mass transfer at the liquid vapor interface. The nature of this phenomena is imperfectly understood. A knowledge of the water vapor interface, the water structure at the interface, and a method to reduce the interface resistance would markedly increase the efficiency of distillation processes. Studies concerned with the structure of water and the properties of the liquid vapor interface are to be expanded.

Materials.—Approximately 50 percent of the cost of desalinated water consists of the capital investment in the desalination plant. Large-scale desalting plants will require new approaches and imaginative ideas in order to make significant reductions in the costs and uses of materials of construction. Alternative materials of construction to the presently used ferrous materials will be investigated. The mechanism of attack of hot brines on concrete will be determined, and new concretes resistant to these brines will be investigated. The use of epoxy, PVC, and polyester fiberglass, ceramics, and other plastic materials for pipe, fittings, and pump components will be evaluated. The fundamentals of the adhesion of these materials to concrete will be probed.

Corrosion.—Salt water is one of the most hostile environments that materials of construction must withstand. A systematic study of corrosion phenomena to define how and why things corrode is in progress. The knowledge developed in this program is expected to lead to an understanding of the mechanisms of corrosion and to point a way to avoid it or to minimize it. The program can be accelerated and the information developed will be used to assist in the selection of materials for large-scale desalting plants.

Brine disposal, heat pollution, large-scale desalting plants will pose a potentially severe threat to the aquatic flora and fauna in the coastal area in the vicinity of such plants unless measures are taken to minimize the threat. Imme-

diates programs will be initiated to determine the effect of heat pollution and brine disposal on aquatic environments, and how these effects possibly can be turned to advantage to improve the aquatic environment.

Increased emphasis will be placed on more economical methods for the recovery of potentially valuable byproducts, such as potassium, trace elements, fertilizer materials, etc.

Size of the program

The specific areas of research proposed above are related and interdependent. For example, in order to treat the problems of nucleation, growth, and transport in the freezing of saline water, we must understand better the generalities of transport processes, and the thermodynamic properties and detailed structures of the substances involved. Similar examples could be offered for all other desalination systems. In each case, there are good clues to the fundamental questions, enough to make scientists and engineers believe that further study is warranted. As the program has increased in size and stature, increasing numbers of highly qualified and competent scientists and engineers are inspired by the opportunity the problem presents to devote their talents to the generation of the knowledge required to solve the problems of saline water conversion. By its very nature research requires freedom for the investigator to follow where his curiosity and interest lead, and confidence from the administrator, since some studies will pay off handsomely and others will yield less impressive results.

Currently proposals are being received in areas relevant to saline water conversion at a rate of approximately 600 per year. Thirty to forty percent of the proposals submitted suggest programs which are sufficiently meritorious to warrant support by OSW. The present funding of the research program allows for support of less than half of the meritorious proposals received. Indeed, as the program has become better known, it has attracted proposals from an increasing number of the Nation's foremost scientists and engineers, and it has been necessary to turn down an increasing proportion of proposals having high merit, in spite of the generally increasing level of support.

The ultimate success and the extent to which desalination will become the method of choice for water supply in water-poor areas will depend in no small measure on our ability to attract and support the country's top talent in working on desalination problems. The proposed program for research will allow support for a greater fraction of those programs that can make significant contributions to the saline water conversion program.

The research program will insure the successful exploitation of the currently most developed technology and the vigorous and imaginative pursuit of other alternatives which may well prove to be superior in the long run. In conformity to the classifications of the Federal Council of Science and Technology, the program has been divided into the following four broad categories.

1. Properties of water

The purpose of this effort is to obtain a comprehensive theoretical understanding of water and water systems to serve as a basis for separation and purification processes. The proposed program is required to achieve thorough knowledge of the thermodynamic properties of saline solutions that is essential to the understanding and evaluation of any desalination process. It is expected that these activities will soon eliminate the serious deficiencies of experimental data and understanding of the properties of multicomponent saline solutions, of ionic hydration and on the fine structure composition of pure water. A major improvement in the present status of theory concerning these phenomena and the liquid state itself will have been made.

2. Separation processes

The investigations on separation and purification processes are designed to provide new information on thermodynamics, electrochemistry, phase and chemical equilibria and kinetics, and mass and energy transport in both physical and biological systems. This research is essential to further knowledge applicable to existing or potential saline water conversion processes, to evaluate ideas for new desalination techniques, and improve the technology and economics of known desalination methods. Analysis of present desalting technology and the anticipated technical advances indicate that no one desalination process will be adequate for all desalination requirements. In the next 5 years it is expected that the reverse osmosis process will move from the laboratory and pilot plant to the demonstration state. The energy requirement of present desalination proc-

esses is many times the theoretical minimum energy requirement. The research program is designed to drastically reduce the energy losses inherent in distillation, freezing, and other processes. Research under this category also includes general studies of ion exchange, effect of magnetic fields, fundamentals of freezing, polymer films, electrochemical separations, energy and material transfer and many others.

3. *Interactions at boundaries of water systems*

Inefficiencies in conversion processes are largely a result of events at surfaces or phase boundaries. The purpose of these studies is to understand and make use of physical and chemical processes on surfaces and at interfaces, and of colloid systems for separation and purification of water. Within the near future, boundary layer problems, corrosion, mechanisms and rate of deposition of scale, and the interaction of materials with salt water systems will be far better understood, resulting in substantially lower capital investment for desalination plants of a given capacity.

Research projects in this category include studies on corrosion under various process conditions, with varying velocity, concentration, pH, oxygen content, heat flux, etc.; electrochemical corrosion mechanisms; corrosion prevention; corrosion of concrete; etc. These projects result in a very complete and comprehensive investigation of practically all phases of corrosion. Other current fundamental research investigations deal with ion transport across plant and microbial membranes, mass transfer in beds of particulate solids, effect of acoustical vibrations at interfaces, and others. It is hoped an accelerated and intensified effort on the development of improved materials (metals, alloys, concretes, polymeric materials), components of plants, etc., soon can be initiated.

4. *Properties of brackish waters, salts, brines and byproducts*

The objective of these studies is to obtain more economical separation processes by integrating saline water conversion with other endeavors such as mineral recovery, use of low-temperature energy, power generation, and combination with existing water systems. The particular problems associated with desalting brackish waters will receive detailed attention. Considerable emphasis will be devoted to brackish resources, minor constituents, biochemistry of, etc.

The minerals contained in saline waters are potentially available in unlimited supply. Multipurpose plants producing both power and potable water already have been designed. It is expected that the economic advantages of multipurpose plants, as well as mineral recovery, will soon be demonstrated. Currently under investigation are properties of sea water and its concentrates, nucleation of electrolytes, influence of vibrations on deposition of salts, minerals from sea water (e.g., potassium, magnesium, etc.), and the mechanism of calcium sulfate scale deposition. The proposed program will extend these studies and initiate a program directed to brackish water desalting.

Although the accomplishments of the research effort have been notable for such a short period, the present store of scientific information is not adequate to support all of the objectives of the desalination program. A sustained prodigious effort in fundamental research will be required before the solution of this most difficult problem can be attained.

STATEMENT OF DR. J. A. HUNTER, ASSISTANT DIRECTOR FOR ENGINEERING AND DEVELOPMENT, OFFICE OF SALINE WATER

ENGINEERING AND DEVELOPMENT

The engineering and development function in OSW has the responsibility to provide and demonstrate practical and economic technology for desalting water. You will very shortly be given details on the work in progress and the potential performance of the various processes. I should first like to present our objectives as we see them.

The basic objective of OSW is to make water desalting available as an economic and reliable source of fresh water to municipalities or areas where other sources are limited or overly costly. Since we do not expect to build these plants, we have a secondary objective, which is to bring industry to the position of marketing such plants. This objective is accomplished by making available the tech-

nology developed under OSW auspices, by spreading the base of our contracts and by helping industry understand the water problem.

Water problems vary extensively for different users. Some locations have sea water—other brackish water and there are great differences in various brackish waters. Some users require hundreds of millions of gallons of water each day and others a few thousand gallons. In some situations there is also a demand for electric power while others may not be able to effectively absorb the electrical energy produced in a dual-purpose plant. In some areas energy is cheap while in others it is expensive. Some need water today—while others have time before the problem is critical.

Accordingly, you will see in our program the development of a wide variety of processes, since we know of no single process which is always "best" or even one which has such a potential for the future. Our Research Division will of course continue a broad program of basic research which may lead to the discovery of such a single "best" process but inventions cannot be scheduled and the engineering work must therefore be directed toward refining the processes we now know. The refinement of each of the various processes follows well established engineering development procedures—i.e., study of concepts; construction, test and analysis of bench-scale equipment; incorporation of these results into larger pilot-scale equipment; and so on until large plants are achieved. New ideas are fed into the system at a point compatible with the uncertainties involved. Furthermore, by this multiple-process approach we also provide the foundation for the growth of a competitive industry with the result that the innovations and abilities of many companies will assist us in achieving our basic objectives of making desalination available as a practical source of fresh water.

Individual companies will tend to associate themselves with one or two lines of technology. Thus while some companies will undertake to exploit freezing, others will associate themselves with distillation and still others with electrodialysis. The various processes each have particular advantages and particular situations where they are most effective. Any individual company will of course be interested in expanding the competitive area of its chosen process. All will face competition from other sources of water. We can therefore count on industry to carry on the refinement of a process once OSW has carried its development to the point where marketable technology is available.

Considering our responsibility to the political subdivisions who will be users of these plants, we believe that marketable technology must be interpreted as technology which will permit a user to buy a plant which will operate reliably without highly skilled operators; which employs a process well suited to the particular requirement; which will produce water at the costs expected when the contracts was let; and which does not require those communities which face a critical problem today to bear the full financial burden of developing the basic technology to the advantage of other communities who can wait a few years.

The present program of engineering and development reflects our best judgment on a proper balance of effort to meet the requirements for different types of plants taking into account the stage of development and demonstration of the various processes, and their ultimate potential for economic water production.

STATEMENT OF J. J. STROBEL, CHIEF, SPECIAL PROJECTS DIVISION,
OFFICE OF SALINE WATER

SPECIAL PROJECTS

Special Projects includes applied research, engineering development, testing, and evaluation, with respect to crystallization processes including freezing and hydrates, ion exchange processes, and special research and development projects related to all processes such as equipment components, deaeration, byproducts, water pretreatments, and brine disposal. Developments are undertaken on new promising approaches or new concepts for saline water conversion processes including those stemming from the basic research program which may lead to improved and lower cost conversion techniques than possible through the use of existing processes.

CRYSTALLIZATION

Introduction

The application of refrigeration principles to the desalting of water was reported in the literature as early as 1945. Meaningful efforts in this area of research, however, were initiated in the 1950's with the increasing interest in saline water conversion and because of the potential advantages of freezing over more conventional processes such as distillation. These advantages as compared to distillation are (1) no scale formation problem, (2) lesser tendency toward corrosion, and (3) a lower energy requirement to bring about conversion. To preserve these advantages, freezing of sea water is brought about by direct methods of refrigeration, thus eliminating the expense of metallic surfaces, and making use of less energy. This can be accomplished by flash evaporation of a portion of precooled sea water under reduced pressure or by vaporizing a refrigerant such as *n-butane* in direct contact with sea water. In either case the latent heat must be recovered and used to melt the salt-free ice. This is accomplished by compressing and condensing either water vapor or refrigerant vapor on the ice.

In commercial operations it would be necessary to carry out the freezing and wash-separation operations as rapidly as possible and to maintain the bulk of equipment per unit of potable output as low as possible to achieve maximum economy. It was found in early investigations both at the laboratory and bench-scale level that rapid production of ice gave rise to the formation of very small ice crystals. Because of their small size and large number, the ice crystals presented a large surface area to which a large amount of the brine adhered and made the separation of ice brine mixtures exceedingly difficult. The immediate problem, therefore, facing freezing technology was that of devising an efficient low-cost method of separating ice and brine and/or developing a suitable control method for growing large ice crystals which would facilitate washing.

At the present time it appears that the freezing processes will be most advantageous in small or intermediate size sea water conversion plants. That is, plants up to 10-million-gallons-per-day capacity of fresh water production. They are also expected to be advantageous in many brackish water applications where usually smaller conversion plants can meet the water requirements. Under these circumstances and applications, lower cost fresh water than obtainable by any other conversion processes can be anticipated.

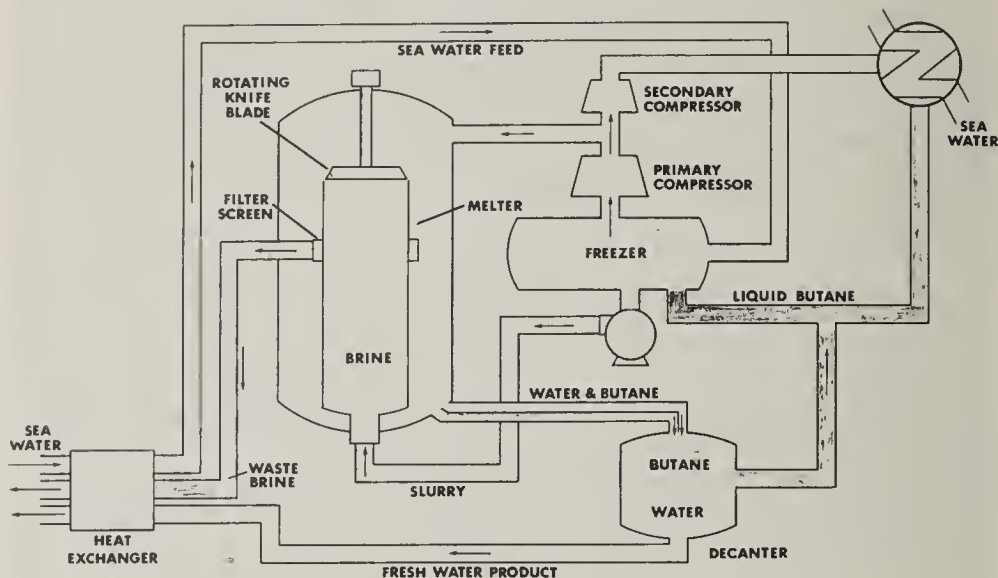
Secondary refrigerant

In 1958, the Office of Saline Water initiated studies to determine the feasibility of a freezing process in which a hydrocarbon such as butane was flashed in direct contact with sea water. The resulting slurry, consisting of ice and brine of 50 percent solids content was processed and the washed ice crystals were melted by the condensation of compressed butane vapors. From out of these early studies grew the concept of the wash-separation column which employed the principle of the hydraulic piston in both the separation and washing steps.

The process flow sheet is shown in figure 1. Sea water is cooled by reject brine and product water leaving the process. The sea water enters the freezer and is mixed with butane. The evaporation of butane lowers water temperature to freezing point and forms pure ice crystals mixed with brine. The ice-brine slurry is pumped into the bottom of a large column where the ice is compacted into a porous bed. The flow of brine through the pores of the bed (hydraulic piston bed technique) created a positive pressure on the bed propelling it upward. The brine flowed out of the column through screens at a point midway up the column. In the upper portion the ice bed was contacted countercurrently with a stream of fresh water to provide either a flooded or a drained bed and a rotating knife blade positioned at the top of the column cut layers of washed ice off into a chute and thence to a melting vessel. The butane vapor removed from the freezer is compressed and condensed on the washed ice in the melt vessel. Fresh water and liquid butane are pumped to the decanter for separation. Liquid butane is recycled to the freezer. Product water is pumped to distribution. Excess butane vapor is compressed by secondary compressor and condensed in auxiliary condenser. Liquid butane is recycled to the freezer. The principle of washing used in this process evolved from the laboratory to bench-scale level and then to pilot plant sizes of about 35,000-gallon-per-day capacities. Although this principle of washing is well established, high efficiency operations and fast throughput are dependent in a large measure on particle size. Thus, to achieve maximum production rates, it was necessary to review earlier freezing concepts

in an effort to grow ice crystals of a large size. Subsequent developments in freezer design and ice crystal growth control indicated that a fairly uniform particle size distribution in the range of 0.75 to 1.5 millimeters diameter was required for practical utilization of wash-separation columns.

BUTANE SECONDARY REFRIGERANT PROCESS



Improved wash column separation has been successfully demonstrated in a 15,000-gallon-per-day pilot plant. Centrifugal separation has also been evaluated in the same pilot plant. Further work has been carried out utilizing different freezer designs to obtain better control of particle size.

The secondary refrigerant method has been successfully employed in a 35,000-gallon-per-day (design capacity) pilot plant. With improvements in wash-separation column technology rates up to 55,000 gallons per day of potable water have been obtained. This pilot plant has demonstrated reliability as well as uniformity of operation. Improved wash column separation has also been successfully demonstrated in a 15,000-gallon-per-day pilot plant. Centrifugal separation is also being studied in this plant. An enlarged version of the 15,000-gallon-per-day pilot plant has been built at Wrightsville Beach and has been designated as the east coast conversion plant. This is a 200,000-gallon-per-day experimental plant built to meet the requirements for a sea water conversion plant on the east coast, as provided in the Demonstration Plants Act. Mechanical difficulties along with design problems in the various unit operations are being studied in order to permit evaluation of the centrifuges as well as other system components.

More sustained pilot plant runs are needed and will be carried out in our present pilot plants in order to refine the various unit operations to obtain data for extrapolation to large capacity plants.

Examples of refinements that are needed in various unit operations are as follows: Modifications to the present freezer designs need further evaluation. Ice cutting devices require additional developmental work in order to devise an efficient method of removing ice from the column to the melter. Additional work is needed to determine the feasibility of direct contact heat exchangers as an economical method of interchanging heat. Further studies are needed in an effort to improve design features of the process so that heat leaks and other inefficiencies are minimized, thus enhancing the economic potential of the process.

In approaching the new program for special projects, cognizance is taken of these problems and plans are projected to continue operation of existing pilot plants with the view toward establishing basic design features. A test bed plant of less than 5 million gallons per day capacity is projected after completion of

pilot plant operations, if developments warrant. On the basis of results obtained from the test bed plant, a prototype plant would be considered a cooperative effort with a water user. Provisions have also been made to implement a development program for components or special hardware which subsequent improvements in freezing technology may dictate. The multistage precooler or prefreezer for the secondary refrigerant system would be an example. Other research and development efforts would lend support when needed before the final design of a large freezing plant is undertaken.

Vacuum freezing-flash evaporation

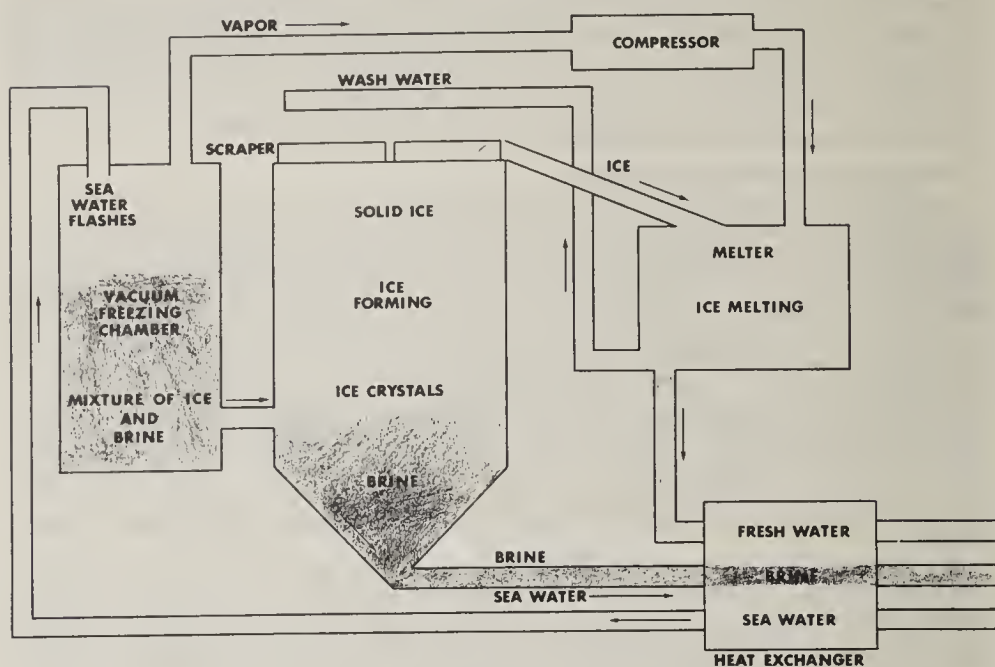
Laboratory evaluation of the vacuum freezing process using an absorption refrigeration cycle was started in June 1956. The successful development of a 300-gallon-per-day bench-scale model subsequently led to the design and construction of a 15,000-gallon-per-day pilot plant. From October 1956 to June 1960, pilot plant studies were made on synthetic sea water after which the plant was relocated at a sea coast location for evaluation on fresh sea water. The pilot plant program was terminated in May 1963. It was shown that in plants in the range of 165,000 to 200,000 gallons per day the process offered possible economies over distillation processes for comparable size plants. The results obtained from this development project established the principle of the hydraulic piston bed displacement technique which has been used in other freezing processes. It was concluded that the use of a vapor compression cycle would give lower costs if low-cost compressors could be developed for handling large volumes of low-density water vapor.

A vacuum freezing-vapor compression process has been developed by industry. This process is based on a low-cost, improved radial compressor and a wash-separation column similar to that developed under the saline water conversion program. The process flow is shown in figure 2. Sea water is cooled by heat interchange with the brine and product. The sea water enters the freezer where 50 percent of the water is converted to ice at a pressure of 3 mm Hg.

The ice-brine slurry is pumped to the wash-separator and the resultant ice bed is propelled upward by the hydraulic piston bed technique as previously described. The ice is washed countercurrently with a portion of the fresh water. The ice is scraped off at the top of the column and conveyed into the melter. The water vapor is removed from the freezer, compressed, and condensed on the washed ice, which results in product water. Development work led to the design of a 60,000-gallons-per-day pilot plant which was evaluated in Beloit, Wis. On the basis of this plant, a four module desalination plant (240,000 gallons per day) was built and shipped to Israel. This plant is presently operating on an experimental basis and supplying potable water to the city of Eilat. Future work in this area of freezing developments will be the evaluation and further development of the 60,000-gallon-per-day pilot plant at Wrightsville Beach to determine the maximum capacity of the plant, and especially of the vapor compressor, at a sea coast location. In order to accomplish the goal of increased output, it is necessary to develop information describing the mechanisms through which the various functions within the freezing process take place. Better performance will permit the determination of ultimate output obtainable from a single module. At the same time the process improvements can be incorporated in design parameters for larger single modules in the 1- to 5-million-gallons-per-day range.

The design and construction of a test bed plant based on vacuum freezing-vapor compression process is planned after completion of pilot studies if results so justify. Actual sizing of the plant will depend on results obtained at Wrightsville Beach. It is believed that the process will show advantages in small size plants either in coastal or inland areas. The latter application may show additional economies when brackish waters of 5,000 to 10,000 parts per million total dissolved solids are used as the feed. This concentration is not too economical for electrodialysis and for many brackish waters not too practical for distillation. The process also offers the advantage of not requiring a hydrocarbon refrigerant, thus there are less safety requirements and no necessity to remove residual hydrocarbon from the product. Brackish waters in certain areas are contaminated with high concentrations of calcium and magnesium sulfates. Since this freezing method is not scale forming, it could have an added advantage in this respect over both distillation and electrodialysis. Later in the program it is anticipated that the vacuum-freeze system could be recommended for prototype plants.

SALINE WATER CONVERSION BY FREEZING

*Hydrate processes*

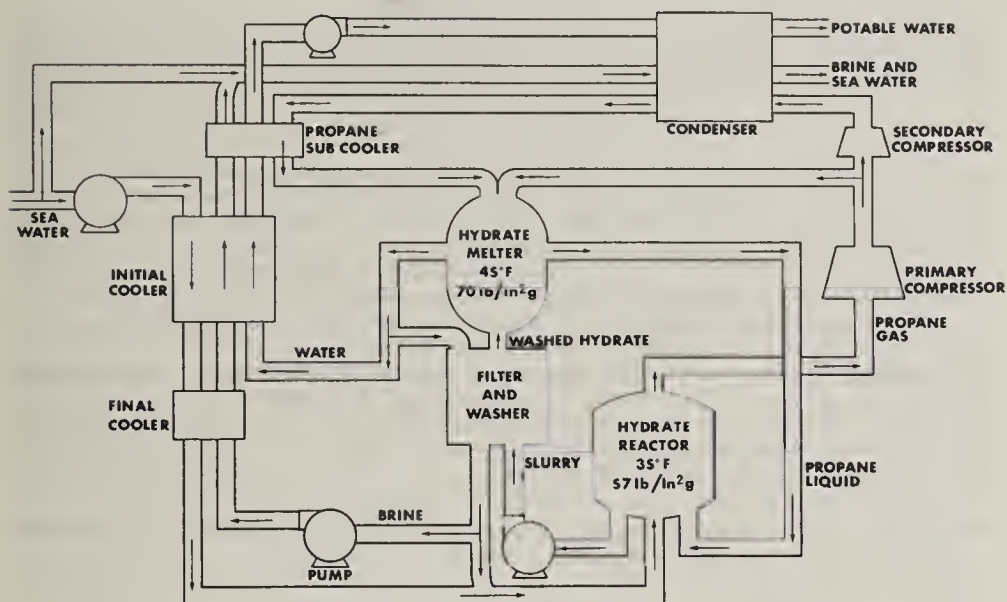
One of the more recent approaches to saline water conversion is that of chemically separating pure water from salt solution by the use of hydrate forming materials. It has long been known that certain compounds such as low molecular weight hydrocarbons or their halogen derivatives combine with water to form solid clathrate compounds which are inclusion complexes in which molecules of one substance are contained or enclosed within the crystal lattice of another component. Like ice crystals, clathrates reject ionic constituents and accept only pure water molecules in their lattice. The crystals are separated from the mother liquor by either filtration, column washing employing the hydraulic piston bed technique, or cyclone separation, then washed free of mother liquor and decomposed into two immiscible liquids: liquid hydrating agent which is recycled and salt-free water. The process flow for the hydrate system is shown in figure 3.

Sea water feed is heat exchanged against product water and reject brine streams. It then enters the reactor where it is mixed with liquid propane at 35° F. and 57-pounds-per-square-inch gage. Propane hydrate crystals form as a solid phase. The propane serves both as hydrate former and a secondary refrigerant to control the reaction temperature. The hydrate-brine slurry is pumped to a filter-washer where hydrate is separated from the mother liquor and then pumped to the melter. Liquid propane from the meter is recycled to the reactor. Propane vapor from the reactor is compressed and condensed on the washed hydrate crystals to effect decomposition to liquid propane and fresh water. Excess propane vapor which does not condense on the hydrate crystals is removed and compressed by a secondary compressor. The vapor is then condensed by heat interchange with sea water, potable water, and waste brine streams. From the melter a portion of the fresh water is cycled to the washer to wash the hydrate crystals and the remainder is sent to storage after heat exchange with the incoming sea water stream. A portion of the reject brine is recycled to the reactor to control viscosity of the reaction mixture while the remainder is heat-exchanged against incoming sea water and then discarded.

Like freezing, the hydrate has several potential advantages over other methods of desalination. It is similar to freezing in that the separation of water involves the formulation of an insoluble phase which must be washed free of brine. Since the hydrate process is operable over a range of modern temperatures, depending on the hydrating agent used, problems of scale and corrosion are minimized. From the standpoint of energy considerations, the hydrate process has an ad-

vantage over freezing. For example, in pure water ice exists at 0°C ., whereas propane hydrate exists at 5.7°C . This difference of 5.7°C . is also maintained in salt solutions irrespective of concentration. Thus, the propane hydrate process, operating at temperatures above those employed in freezing, offers the potential advantages of lower energy requirement and investment costs.

PROPANE HYDRATE PROCESS



In 1959 the Office of Saline Water supported, under a cooperative contract, the development of a hydrate process based on a patented process. Most of the work was carried out in bench-scale equipment including a 10-gallon reactor-crystallizer with a capacity equivalent to 150 gallons of potable water per 24 hours. In addition, laboratory research was done on the hydrate forming reaction and calculations were made to evaluate the processing steps and to determine the order of magnitude of the production costs. In this process, two methods of washing the hydrate crystals have been investigated at the bench-scale level. These methods are (1) filtration and (2) column washing using the hydraulic piston bed technique.

In view of the promising bench-scale work, a 10,000-gallon-per-day pilot plant to evaluate this process is being built. Scaled-down experiments will be conducted in the pilot plant on the two different methods of wash separation in order to determine which method will be used for additional pilot plant studies. The pilot plant is expected to be completed approximately September 1965.

Also being investigated is another hydrate process which employs cyclones for washing the hydrate crystals and which is based on a different patented version with potential advantages. This process had an initial development by industry in a small 700-gallon-per-day pilot plant. In May 1962 this Office supported the further development of this process in this 700-gallon-per-day pilot plant. The results of the investigation indicated considerable promise.

In order to further develop the process, this Office supported through contract the design and construction of a 20,000-gallon-per-day pilot plant at the Research and Development Test Station, Wrightsville Beach, N.C. Operational evaluation of the pilot plant was started in April.

The hydrate processes, using propane as the hydrate former, are less further advanced than freezing processes. Although problems similar to those experienced in freezing studies will undoubtedly arise, it is expected that the technology will move ahead more rapidly because solutions to freezing problems will in part be applicable to hydrates.

The projection of test bed plants must await the results from pilot unit operations. However, if breakthroughs are possible within the next year, it may well be that hydrate will advance faster than freezing. The use of cyclones as a wash-separation device may provide a means for increasing capacities with no large increase in equipment size. Then, too, the use of filtration or column

separators may also work to a greater advantage with hydrates than with freezing. The hydrate system may require further research and development support particularly in component development and design. However, it is somewhat early to pinpoint any specific problems at this time. The results of pilot plant operations will define more clearly the problem areas, and the justification for further development effort.

ION EXCHANGE PROCESSES

Ion exchange processes pass saline water through an ion exchange material. See figure 4 for typical ion exchange flowsheet. This material has the ability to exchange one ion for another, hold it temporarily in chemical combination, and give it up to a strong regenerating solution. Salt can thus be removed from saline water. Ion exchange desalination has been used effectively to obtain small quantities of fresh water from sea water in special applications, such as emergency kits for liferafts. A few Department of Defense installations, such as radar warning stations, have successfully used ion exchange desalination for producing limited quantities of potable water from brackish water. Also, ion exchange demineralization has shown advantages for obtaining fresh water of comparatively low dissolved solids for special industrial and other uses. Ion exchange processes have been too costly to consider for desalination of appreciable quantities of sea water or highly brackish water. However, in recent months there has been an announcement of several developments by commercial firms which make use of newly developed ion exchange resins together with new approaches to regeneration of the resins, which may make ion exchange desalination less costly than electrodialysis in certain locations when applied to waters up to 3,000 parts per million total dissolved solids. Thus, a test bed plant (500,000 gallons per day or two 250,000 gallons per day) should be ready for construction within several years. New approaches or any additional development will also be considered. Ion exchange processes may be adaptable in certain locations to treating polluted waters, such as acid mine waters.

Typical Ion Exchange Desalination Process

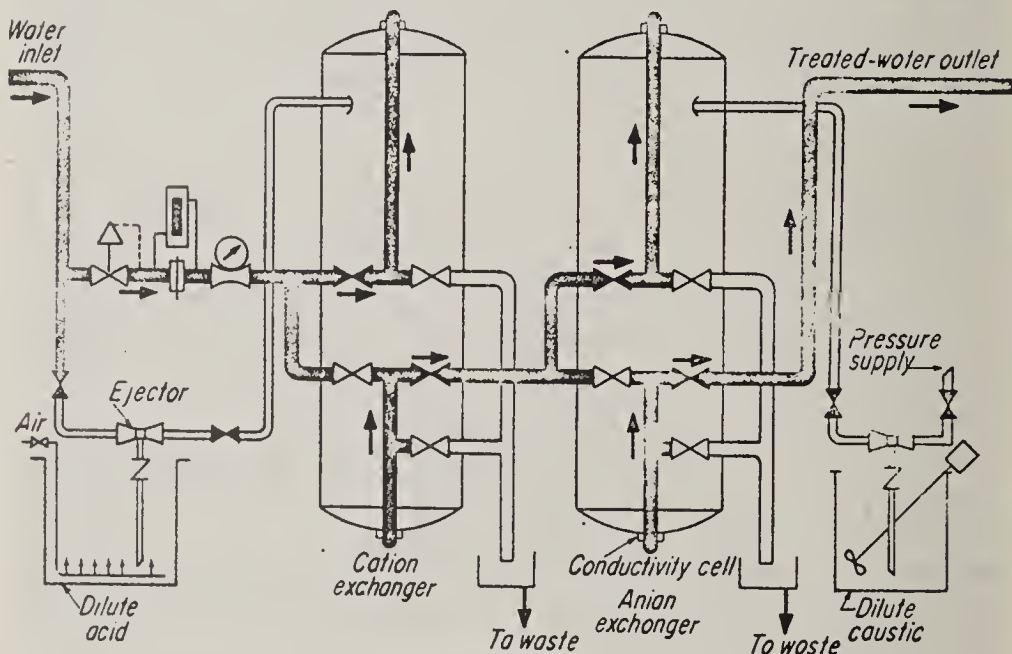


Figure 4

BRINE DISPOSAL

Brine disposal at coastal locations became much more of a problem when current plans for large sea water conversion plants were adopted. Disposal of waste brines from inland areas has been recognized as a problem for sometime but has not yet been satisfactorily solved although preliminary investigations have been conducted. The proposed program on brine disposal includes research and development studies to determine the effects of brine disposal factors on aquatic environment, and inland areas. Environmental studies will be undertaken in the laboratory and in the field. They will include engineering and cost studies relating to submerged offshore piping, subsurface injection, ponding, solar evaporation, and other possible means of brine disposal or use (e.g., byproducts).

PRETREATMENT AND BYPRODUCTS

The pretreatment of saline water feeds prior to conversion processing is an effective means of reducing scaling problems, particularly in distillation systems. Chemical pretreatments also make possible the production of useful byproducts from sea water, such as certain potassium and magnesium compounds. Experimentations with actual conversion plants both in the pilot plant and demonstration plant operations have shown that filtering is needed to remove suspended materials, organic materials of various types, and other materials detrimental to processing. More study and evaluation will be undertaken to determine the most suitable type and adaptations of conventional filtering and pretreatments to problems of saline water conversion.

A pilot plant is now operating at the research and development test station to obtain data on several chemical pretreatment methods, as well as several byproduct recovery methods. Ion exchange pretreatments to soften sea water were developed in pilot plant size; they can be used now in conversion plants although further improvements are being made. A method of this type was incorporated in the Roswell demonstration plant and is now being tested and evaluated.

Concentrated brines which are waste products from conversion plants may also be sources of useful byproducts. Studies of this possibility have, in recent years, been more favorable because, through various process improvements in distillation, it is now possible to obtain higher waste brine concentrations than previously, and also because of the concept of large plants. However, a word of caution is necessary in that economical recovery of byproducts, either from the chemical pretreatment process or from a process which treats the waste brine, is dependent upon market conditions, size and location of plant, type of conversion process, and so forth.

POLLUTION

As used in the act under which the Office of Saline Water operates, the term "saline water" includes sea water, brackish water, and other mineralized or chemically charged water. Some polluted waters will require desalination processes, either separately or jointly with processes being developed by HEW to treat polluted waters *per se*. Acid mine waters, in certain cases, might be treated by some desalination process. More research and development on pollution problems is needed. Contributions to the state of the art (prototype plant) in pollution abatement or control, including acid mine water drainage problems, is anticipated at the time new approaches to these problems become developed far enough for practical applications by user organizations.

STATEMENT OF E. N. SIEDER, CHIEF, DISTILLATION DIVISION, OFFICE OF SALINE WATER

PROCESS DESCRIPTION AND PRESENT STATUS

Mr. Chairman and members of the committee, the Distillation Division is concerned with three general categories of distillation processes; namely:

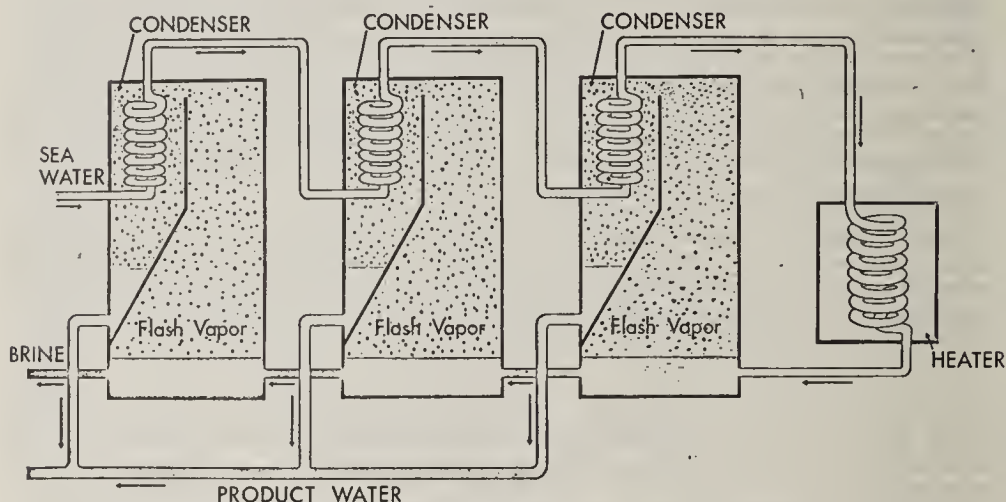
1. The multistage flash system as used in the San Diego demonstration plant now at Guantanamo,
2. The long tube vertical multiple-effect system as exemplified by the Freeport demonstration plant, and
3. The vapor compression system now being demonstrated at the OSW plant at Roswell, N. Mex.

MSF

The multistage flash process, often called MSF, is so named because steam flashes from hot brine in a series of chambers or stages. The steam is condensed on cooling coils, associated with each flash chamber, to make fresh water. This process is further along in its development than the other two processes and is used in most production plants throughout the world.

The 1-million-gallon-per-day OSW plant in San Diego was the largest and most efficient of its kind when built. It eventually operated at 140 percent of design capacity. Technology developed in this plant has been incorporated in several recent production plants, one of which has a capacity of 1.7 million gallons per day.

FLASH DISTILLATION

*LTV*

The long tube vertical (LTV) process has been used for years in various industrial evaporator systems, but until recently it has not been considered highly as a potential source of municipal and industrial water.

The 1-million-gallon-per-day OSW plant at Freeport, Tex., using this process, consists of 12 effects or individual evaporators, each comprising a bundle of long vertical tubes surrounded by a steam chest. Salt water is introduced in the top of the tubes and is partially vaporized as it flows downward on the inside of the tube walls. The steam so generated is used as a heating medium in each successive effect to cause further vaporization of the salt water feed; a high economy is thereby obtained as the heat of the initial steam is used over and over again. The steam, condensed in each effect, becomes the fresh water output from the plant. The Freeport plant, although getting off to a poor start, has for several years successfully made water at rated output and recently has demonstrated the possibility of producing water at 40 percent over capacity, if pumps were available to take it away. This process is now considered to be a close competitor of multistage flash.

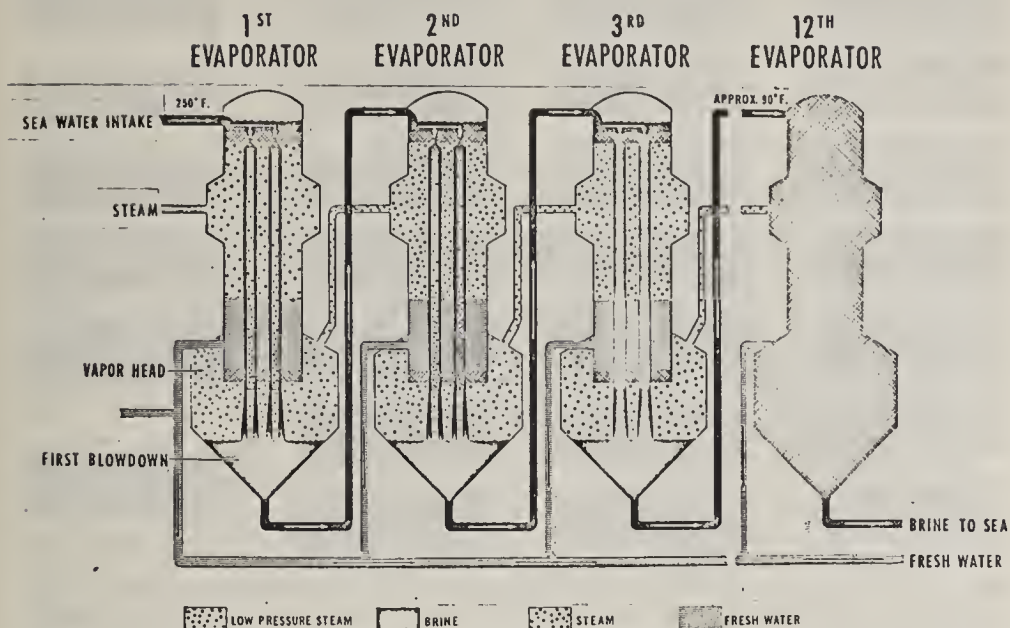
Vapor compression

The vapor compression process has been used commercially for over 25 years. Vapor-compression packaged desalting units were used by the Armed Forces in World War II. They are still being offered commercially for resort hotels in water-short areas and for shipboard use. The process to date has been characterized by high-water cost and troublesome maintenance.

The vapor compression distillation process derives its name from the fact that the steam, produced by the initial evaporation of the brine feed, is pumped up to a higher pressure and consequent higher condensation temperature by a compressor where it is then utilized as the heat source for initial evaporation. The steam, after condensation on the evaporator tubes, is pumped away as the fresh

LONG TUBE VERTICAL DISTILLATION PROCESS

DEPARTMENT OF THE INTERIOR - OFFICE OF SALINE WATER



water product. The Roswell, N. Mex., 1-million-gallon-per-day demonstration plant, which is of this type, met guarantees during the start-up period, but has since been plagued with hydraulic and scaling difficulties. The process is unique in that energy is added by the compressor rather than as heat. It can operate with any conventional power source to drive the vapor compressor; e.g., electric motors, Diesel engines, or gas turbines.

The vapor-compression system is most promising where low-cost or off-peak electric power may be available and where cooling water and fuel are at a premium. This system is sometimes known as the heat-pump process.

Point Loma replacement

The first and most important step, in our opinion, is to start construction of the advanced-technology San Diego replacement. The design, specifications, and bid package are complete and ready for release for bids. Schedules call for about 60 days for letting contracts and a year for construction. This plant will be of the multieffect, multistage system which incorporates such advanced features as:

1. High efficiency—twice the water output per pound of steam of any present-day plant.
2. Reduction in size of critical features, such as flash chambers, thus decreasing the overall cost of the plant.
3. The ability to operate at high temperatures and to utilize advances in scale reduction technology and byproduct processes.
4. More sophisticated instrumentation and automatic control systems.

The construction and testing of this plant is necessary prior to design and construction of second generation flash plants.

Freeport

Plans for the Freeport plant call for installation of tubes of special configuration and design which should give higher heat transfer and much improved performance. As the cost of tubes in an evaporator may represent as much as 40 percent of its total cost, improvement in this area is important. Provision for special feedwater treatment methods are also planned for this plant to be in use within the next year. It is projected that the Freeport plant, when modified, will produce water at a cost 20 percent less than at present.

Roswell

The modifications planned for the Roswell plant will be directed first toward better scale control and correction of hydraulic deficiencies. Future plans call for major changes in compressor design or addition of entirely different compressor concepts which show promise in the pilot plant stage.

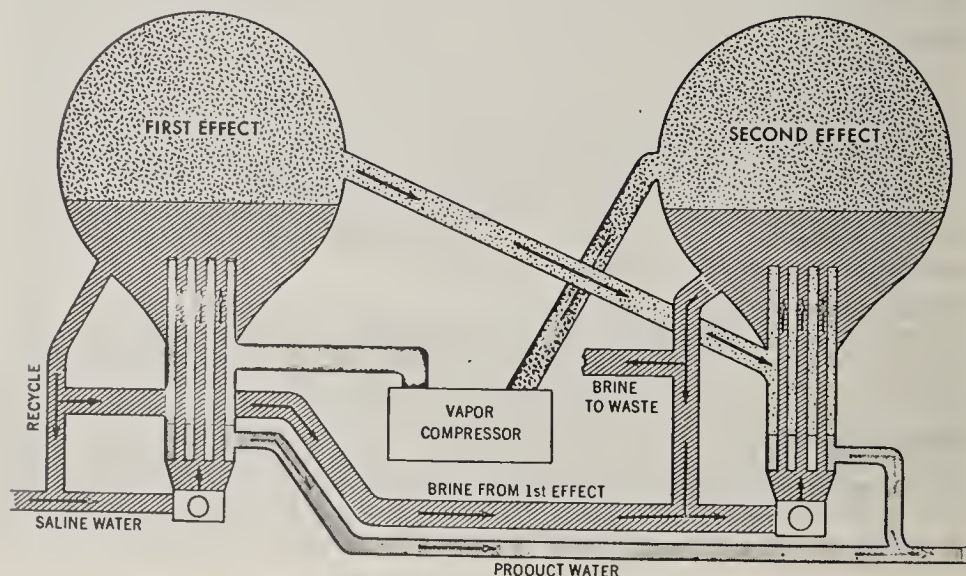
LARGE PLANT PROGRAM

Conceptual design studies

Conceptual design study contracts for a 50-million-gallon-per-day plant have been issued to 15 contractors—architect-engineers, fabricators, and constructors. The purpose of these conceptual design studies is to have contractors present their ideas of processes and structural designs through the medium of a complete plant concept and supporting data. Such concepts must have received detailed study by them, and have been optimized by them, to indicate the lowest cost of water. The plant is to be designed on the basis of ground rules provided by the Office of Saline Water. These ground rules provide that the plant be capable of operating in conjunction with an electric generating plant, that it be suitable for a west coast site, and that it use technology based on known concepts, or data proven at the production or pilot plant level.

From these design studies, the Office of Saline Water will attempt to obtain the best composite or individual design concept for the development of a prototype plant. It is hoped the studies will lead to solutions of mechanical problems involved in large size desalting plants. The overall program will provide an economic evaluation of several known processes or combinations thereof. Although the ground rules provide that the evaporators be operable with dual-purpose plants, the information from the studies will be useful in future studies on single-purpose plants.

In addition to the 50-million-gallon-per-day conceptual studies, the Office of Saline Water has contracted with the Oak Ridge National Laboratory for an advanced technology, 250-million-gallon-per-day flash process conceptual design. This study is being made in much greater depth than the other studies and will consider features not yet reduced to practice nor necessarily proven in pilot plant studies. This evaporator system is to operate in a dual-purpose plant in conjunction with advanced reactor designs now under consideration by the Atomic Energy Commission for 1975 operation. Additional studies of this nature may be undertaken for the Office of Saline Water by Oak Ridge National Laboratory on other evaporative processes.

**FORCED CIRCULATION,
VAPOR-COMPRESSION DISTILLATION**



Supporting studies

Supporting studies have been initiated to develop the best components for critical areas in the plants of the future. These detailed investigations will be applicable to many or all of the distillation processes. Studies are being conducted by the Bureau of Reclamation at its Denver laboratories to generate technology necessary for the use of concrete for major components of large evaporator plants. Large test loops are being operated under conditions closely approximating those which will occur in the prototype plant. The Bureau of Reclamation is also assisting the Office of Saline Water in large pump studies. Contracts have been let to certain pump suppliers for designs and specifications for large pumps needed for the prototype plant. Information on pumps of this size under the required operating environment has not been developed up to this time since the need has not existed.

Studies of other major components, such as jets, blowers, compressors, tubes of special configuration, and tube bundles are being made by the Oak Ridge National Laboratory for the Office of Saline Water. The facilities of industry are also being used through contracts for the construction and operation of pilot plants based on the multieffect, multistage principle, and studies of large-scale flash chamber geometry. Studies are being undertaken on flashing devices which are the heart of any flash distillation system.

The results of all of these studies should allow a decrease in margin of over-design without increasing the risk of performance failures in future plants.

Modular studies

The construction of modules and test sections of a new plant which represents a large scale-up factor from the present plant size is considered to be a necessary intermediate step. A module, as the term is used here, is a full size, or approximate full size, cross section of a large plant. It would consist of several full size flashing stages with accompanying pumps, instruments, control and air removal systems. In scaling up from the largest plant of known performance, in the case of desalting from about 1.7 to 50 million gallons per day, there are many hydraulic and mechanical problems that must be solved before committing ourselves to the considerable expense of a full-scale plant. It is expected that through these modules we will be able to prove our concepts of hydraulic flow, heat transfer, and construction techniques before committing ourselves to the large plant, thus eliminating financial risks and possible delays in schedule.

Metropolitan water district

The Metropolitan Water District of Southern California, together with Interior and AEC, entered into a contract with the Bechtel Corp. for a detailed study to determine the engineering and economic feasibility of a combined nuclear-fired desalting and electric generating plant, producing water in the range of 50 to 150 million gallons per day with 200 to 750 megawatts of electric power.

The scope of work called for in the study is divided into three phases:

Phase 1 consists of a preliminary survey of possible sites on the southern California coast suitable for producing desalted water and with a means for introducing such water into metropolitan water district's distribution system. This phase will cover the economic feasibility of the several sites.

Phase 2 requires that a detailed investigation be made of such sites, selected under phase 1, which will include a determination of power-water production ratios, operating flexibility, and powerplant parameters based on the system requirements.

Phase 3 calls for a complete conceptual design of the optimum desalting and powerplant as determined from investigations of phase 2. This phase will provide detailed capital cost estimates, operating costs, and costs of water and power. This phase of the report will make recommendations for use and distribution of the water and the sale of power, and will provide data for use in negotiating with the utilities.

Israel

Under an agreement with the State of Israel, the Department of the Interior, and the Atomic Energy Commission, a contract was let with Kaiser Engineers and the Catalytic Construction Co.

These two contractors, operating as a joint venture, will consider the feasibility of a dual-purpose water desalting and powerplant on the coast of Israel to provide 70 to 110 million gallons per day of desalted water together with 175 to 200 megawatts of electric power. In contrast to the metropolitan water district study, only one site will be considered.

The scope of work calls for a review and evaluation of reactors now commercially available and an investigation of more advanced reactors. The study also calls for the formulation of a development program to insure that there will be no unreasonable risk in meeting performance and that there will be no need for an unnecessary margin of overdesign required in the full-scale plant. The study will compare nuclear and fossil fuel costs and make recommendations as to the final fuel source.

The final report will provide detailed designs, capital costs, operating costs, and costs of water and power from the proposed plant.

Both the metropolitan water district and Israel studies should be completed by the end of the year. Both studies contemplate commercial operation of the plants by 1971-73.

STATEMENT OF DR. GEORGE F. MANGAN, JR., CHIEF, MEMBRANE DIVISION, OFFICE OF SALINE WATER

INTRODUCTION

With existing conversion technology, the most economical methods for converting the majority of inland brackish water supplies to potable water is via membrane processes.

A membrane may be defined as a physical barrier which allows the separation of salt from water by preferentially permitting the passage of salt while restricting the passage of water or which permits the passage of water while restricting the passage of salt. The energy or driving force for the separation may be a difference in concentration of the solutions separated by the membrane, an applied current, pressure, temperature, or a combination of these forces.

Membrane processes possess a number of attractive features which hold promise of significantly reducing the cost of converting brackish water and, with additional development, may find application for the conversion of sea water. Among the attractive features of membrane processes is that no phase change is required to bring about the separation of salt and water. That is, water does not have to be converted to steam and then condensed back to the liquid state. Therefore, energy costs are held to an extremely low value. Also, since membrane processes operate at ambient temperatures, corrosion problems are

minimal and less costly materials of construction may be used. Maintenance costs are also reduced.

The research and development activities in membrane systems, supported and encouraged by the Office of Saline Water have been extremely successful. They have resulted in the electrodialysis process emerging as the most efficient and economical process for the conversion of brackish water in the range of 1,000 to 10,000 parts per million of dissolved salts, and they have resulted in the discovery of an entirely new membrane concept which holds promise for becoming an efficient and economical process for converting the whole range of saline waters from 1,000 parts per million up to, and including, sea water.

In addition, a number of new membrane processes are in the laboratory stage of development and show sufficient promise to justify additional bench-scale development work. They are the "transport depletion" process and the "electrogravitation transport depletion" process.

I would like to describe, briefly, each of the membrane processes to the committee—their advantages and limitations—and the approaches we propose to follow to realize the full potential of the membrane separation processes.

I. ELECTRODIALYSIS

The electrodialysis process differs from other conversion processes in that salt is removed from water rather than the water being separated from the salt.

When salts dissolve in water, they divide into equal numbers of positively charged particles called cations and negatively charged particles called anions. Electrodialysis may be defined as a process in which separation of these ions is accomplished by ion-selective membranes where the energy for separation is an applied electric current. The membranes used have a special property known as "ionic selectivity," i.e., they can be made so as to allow the passage of either positively charged ions or negatively charged ions but not both. A simplified diagram of an electrodialysis stack is shown in figure 1. In the diagram (fig. 1), an electric field attracts anions to the right and the cations to the left. The "ion-selective" membranes allow ions to pass through in one direction only: permeable anion membranes (A) allow anions to pass through from left to right whereas permeable cation membranes (C) allow cations to pass through from left to right. Concentrated brine and fresh water are formed in alternate cells.

In the electrodialysis separation process, the quantity of electric current, the membrane area required and, therefore, the cost of the process depends on the amount of salt removed. Electrodialysis has an inherent economic advantage for desalting brackish water since the electrical energy requirement for separating salt from brackish water is much less than that which would be required to separate salt from sea water.

ELECTRODIALYSIS

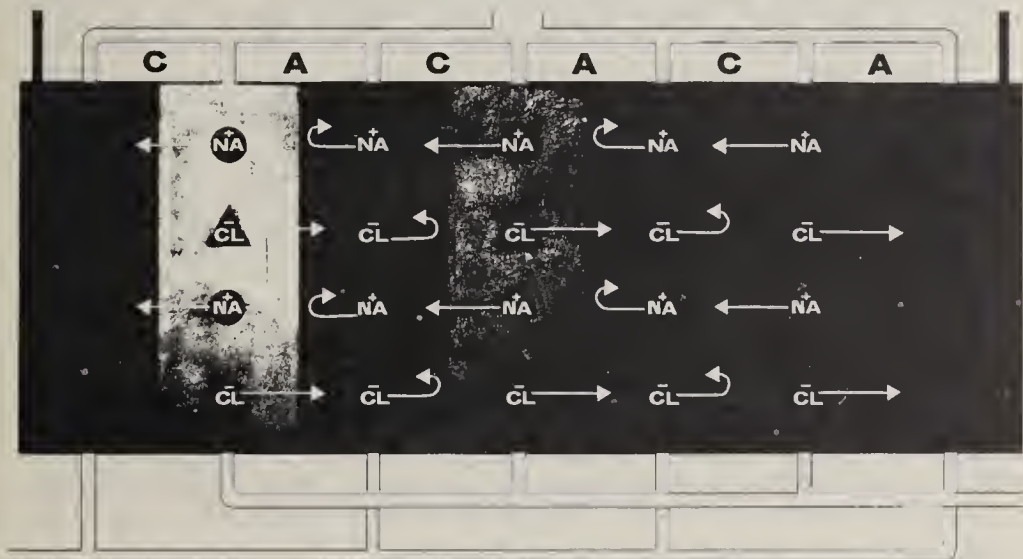


Figure 1

Electrodialysis became a practical reality with the development and introduction in 1948 of stable ion-selective membranes. Prior to that time, ion-selective membranes had low ionic selectivity, high electrical resistance, and extremely short lifetime. After 1948, efficient membranes were able to be synthesized for the first time as a result of new developments in plastic technology.

Following the development of practical ion-selective membranes, commercial development of the electrodialysis system came about rapidly and the first production installation went on stream in mid-1954. At the present time, there are over 100 electrodialysis plants in operation throughout the world. The largest plant currently in operation is the installation in the city of Buckeye, Ariz., which has a design capacity of 65,000 gallons per day.

The economic potential of electrodialysis for desalting brackish water resulted in its selection in 1959 as the process to be demonstrated in the first brackish water demonstration plant. This 250,000-gallon-per-day plant, built at Webster, S. Dak., by the Austin Co. using the Asahi Chemical Industry Co., Ltd., stack design, became operational in the fall of 1961. Since that time, the plant has continuously supplied water to the city of Webster. The plant has generated much useful information, particularly with respect to the economics of the system and the operational problems that can arise during long-term usage of electrodialysis equipment.

A. Electrodialysis limitations: Potential areas of improvement

While today there is relatively widespread application of the electrodialysis process, not all brackish waters can be converted economically.

Significant gains in economy by making improvements in the technology of the process are possible. Potential areas of improvement include development of more efficient membranes and also improved hydraulic system.

To understand where these improvements can be made, it becomes necessary to describe the basic mechanism of ion transport through ion-selective membranes.

When immersed in an aqueous solution, the structure of an ion-selective membrane can be considered to consist of a solid phase and a liquid phase. The solid phase or body of the membrane is an insoluble polymerized hydrocarbon matrix to which are attached fixed ionic charges. These fixed charges are positive for anion selective membranes and negative for cation selective membranes. The membranes are porous and within the pores, or liquid phase, are an equal number of mobile ions of opposite charge.

As an example, a cation membrane of the sulfonated polystyrene type immersed in a solution of sodium chloride is shown in figure 2. Within the body of the membrane, sulfonic acid groups are chemically bound to the insoluble polystyrene network. In aqueous solution, the sulfonic acid group dissociates to form negatively charged fixed ions. At equilibrium, due to the requirement for electro-neutrality, there is an equivalent number of mobile positively charged ions or sodium cations within the membrane. These sodium cations occur within the pores or liquid phase of the membrane and are capable of migration.

If a direct current potential is applied to the system, both the mobile sodium and mobile chloride ions will take part in the transport of electricity through the bulk solution. In the cation membrane, however, it is found that almost all current is carried by the sodium ions. The electrostatic repelling forces between the fixed negatively charged sulfonate ions prevent the chloride ions from entering and migrating through the membrane phase. In a similar manner, fixed positive ions in an anion selective membrane prevent sodium ions from entering into the anion selective membrane. This "ion exclusion effect" is largely responsible for the ion selective action of these type membranes.

This description of ion transport, as given above, is based on an idealized system. In actual operation, electrodialysis is more complex since a number of transport processes occur simultaneously. The major transport processes which occur in ion-selective membranes are shown in figure 3.

Counter-ion¹ transport constitutes the major electrical ion movement in the process. Co-ion transport which also occurs is undesirable and should be made as small as possible; this is dependent upon the selectivity of the membrane and upon the concentration gradient across the membrane. Water transfer, resulting from ion transport, will occur. This can be in the form of water of hydration

¹ All ions in a ion-selective membrane having a charge opposite from the fixed ions; i.e., in the example given previously, sodium cations within the cation selective membrane.

ELECTRODIALYSIS CELL

SINGLE CELL SURROUNDED BY SODIUM CHLORIDE (NaCl) SOLUTION
SALT REMOVED FROM THE CENTER

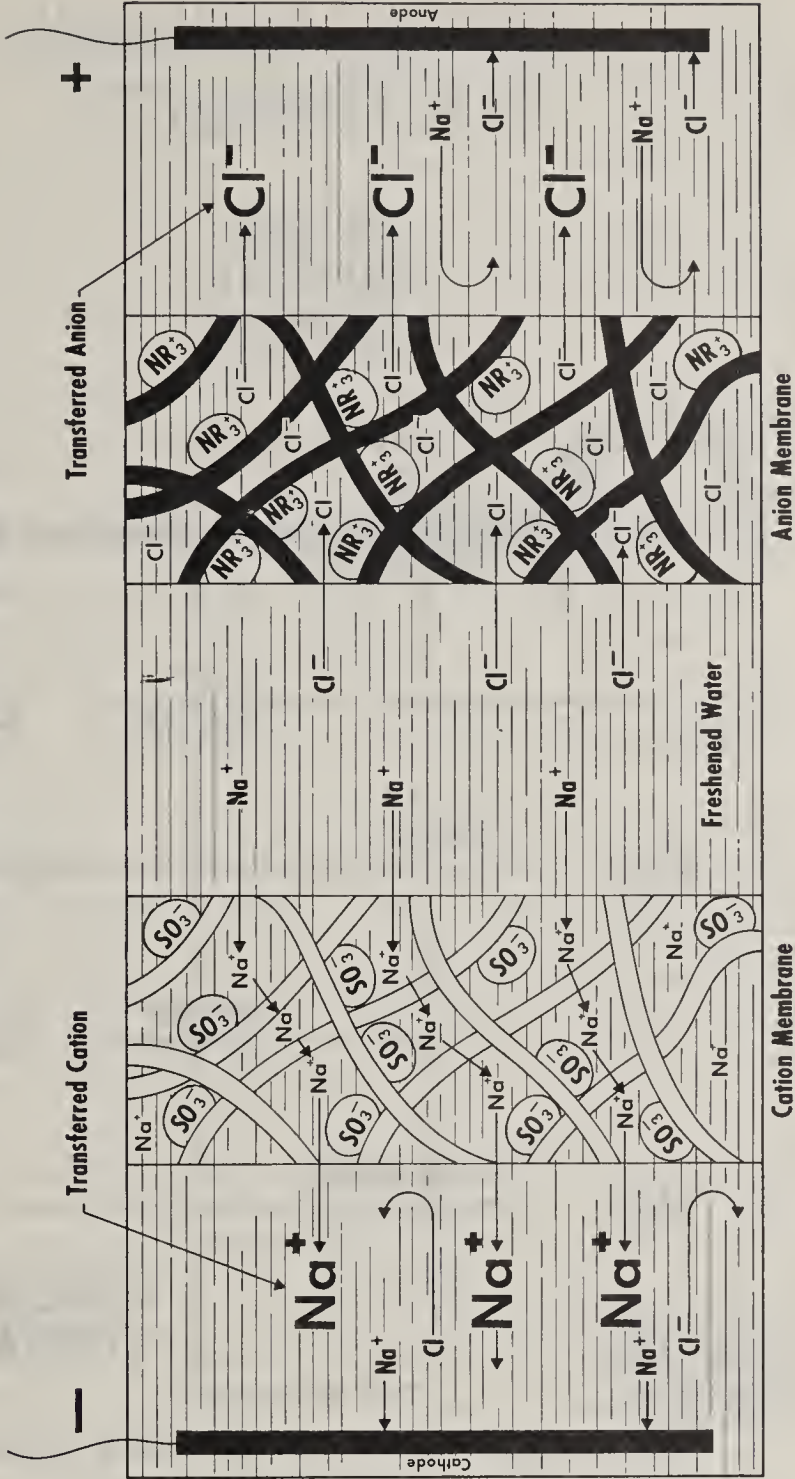


Figure 2

TRANSPORT MECHANISMS IN ELECTRODIALYSIS

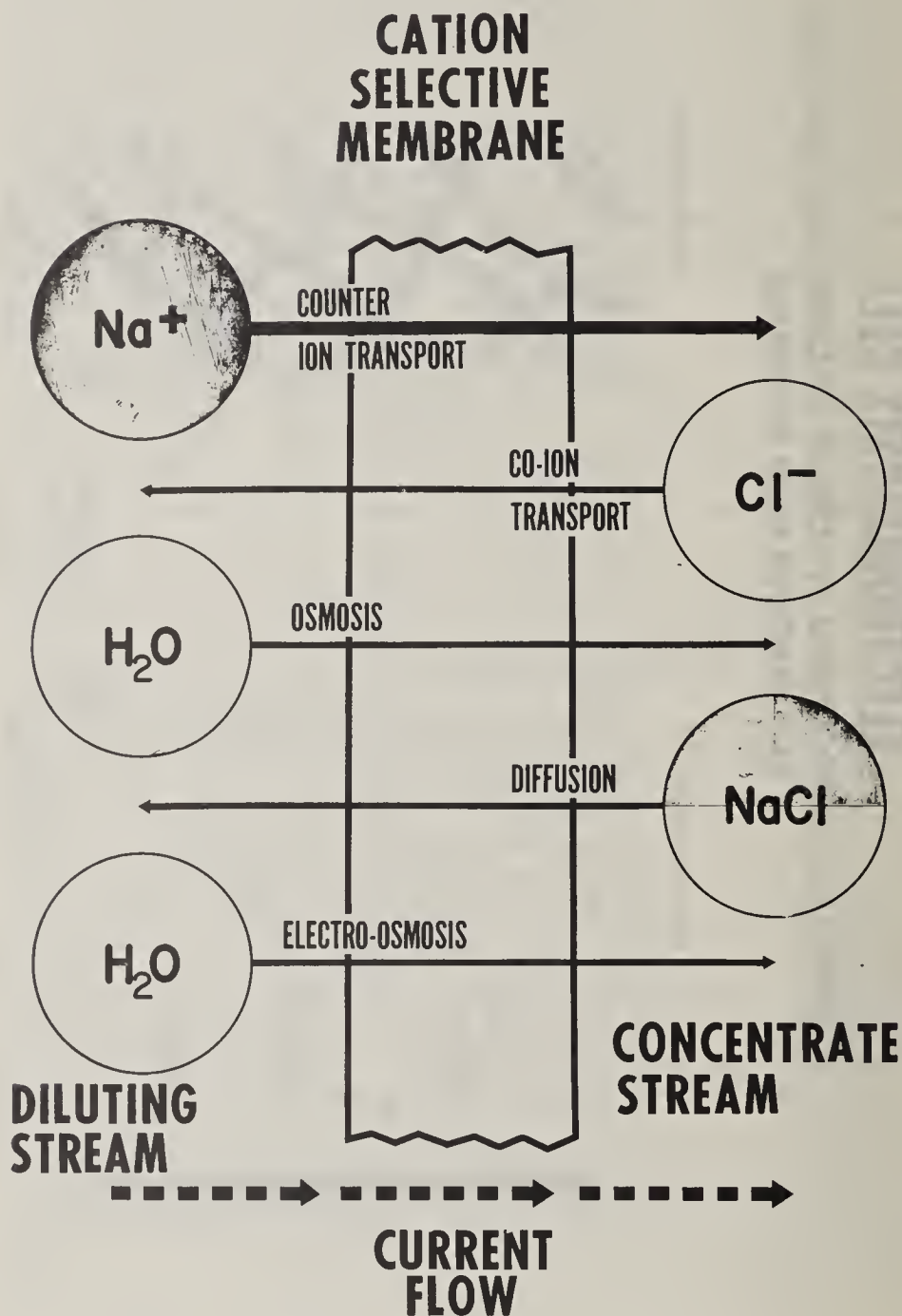


Figure 3

of the mobile ions, such as sodium, and as water carried along with the ions and not tightly bound.

In practical electrodialysis, the total water transfer caused by electrical current is generally referred to as electro-osmosis. Osmotic water transfer also occurs and takes place in the same direction as the salt transfer. Osmosis and electro-osmosis are undesirable effects which tend to limit the usefulness of electrodialysis as a method of concentrating electrolytic solutions. Finally, diffusion of electrolyte can occur from the concentrating stream to the diluting stream due to the concentration gradient.

In summary, the efficiency of the electrodialysis process can be considerably reduced by the counter effects of electro-osmosis and osmosis, diffusion and co-ion transport. These unwanted transport processes can be minimized by the use of membranes with high ion selectivity, that is, negligible permeability toward ions of the same charge as the fixed ions of the membrane by controlling the pore size, and by controlling the distribution of fixed charges within the membrane matrix.

While relatively efficient ion-selective membranes have been developed and are currently in use, there is still need for further improvement to more closely approach the properties of an ideal membrane; in fact, choice of membrane types for any application is likely to be a matter of compromise.

We propose to initiate a membrane investigation and development program to further improve membrane properties. We believe improved efficiencies may be achieved by developing membranes of low resistance, higher charge density, optimum pore size, and minimum thickness. Minimum thickness is desirable from the standpoint of both associated reductions in the cost of membrane surface and an improvement in electrical conductance.

Further cost reductions in the electrodialysis process can be achieved by minimizing the effects of polarization. Polarization or film depletion is a major limiting factor which has kept the cost of water production by electrodialysis high. If it were not for this limitation, plants could be designed to operate at an economic optimum current density in lieu of the lower current density that we are now forced to use.

The phenomena of polarization arises from the concentration gradients which occur at the membrane interfaces. At, or near, the interface of a membrane, the solution will tend to become depleted of ions. If the current density is not too high, the depletion will be largely balanced by diffusion of ions from the bulk solution to the membrane interface. There is, however, a critical current density at which diffusion will be incapable of furnishing electrolyte to the membrane interface. With a further increase of current density, the voltage rises sharply and all the current above the critical value is carried by hydrogen or hydroxyl ions which result from the disassociation of water. This phenomenon is called film depletion or polarization. Polarization causes pH disturbances at the interface, loss of current efficiency, and high electrical resistance. If pH sensitive substances are present in the solution, they may be precipitated causing damage or plugging of the membranes.

We propose to initiate a program with the objective of minimizing polarization effects. As part of this program, improvements in the hydrodynamics of the system will be investigated. Polarization can be minimized by inducing turbulence, and by insuring that local stagnant flow areas are eliminated. This will require improvements in membrane separator designs and the development of methods to induce turbulence in the solution adjacent to the membrane. We also propose to investigate the use of electrical and thermal methods to counter the effects of polarization. Electrical field disturbances or "pulses," created by reversing the polarity of the electrodes, can be used to momentarily disrupt the steady state concentration gradients that occur at the membrane solution interface. This method has been tested at the Webster, S. Dak. electrodialysis plant with promising results. Additional work is required to perfect the techniques and to obtain data over a wide range of operating conditions.

It is known that there is a reduction in solution resistance and, therefore, an increase in the maximum allowable limiting current density as the temperature of the feed water to be demineralized is increased. We propose to investigate the effects of temperature on waters of varying composition in order to determine if preheating the feed water will open another avenue for reducing the cost of converting brackish water by the electrodialysis process.

B. Cost factors in electro dialysis

The cost of converting water by electro dialysis will vary widely due to the strong dependence of the electro dialysis process on the total salinity, chemical composition, and temperature of the water. A recent study was made for the Office of Saline Water to determine the present day cost of electro dialysis conversion for specific base case waters using uniform design and economic criteria. In the study, costs were determined for plants with capacities of 250,000 gallons per day to 10 million gallons per day. The extent of potential cost reductions by lowering of membrane costs and assuming operation at the economic optimum current density was also determined.

The estimated present day cost of converting brackish water at Buckeye, Ariz. and at Webster, S. Dak., is shown in figure 4. These curves are significant because they also show the strong influence of chemical composition of cost. Though the water at Webster has a lower salinity than that at Buckeye, the cost of converting Webster water is about 50 to 80 percent higher, due to the high calcium content and lower temperature of the Webster water. The effect of low cost membranes and operation at optimum current density is shown in figure 5. While these curves are based on a million-gallon-per-day plant at Webster, they would be representative of costs experienced in other plants.

EFFECT OF WATER HARDNESS ON ELECTRODIALYSIS CONVERSION COSTS

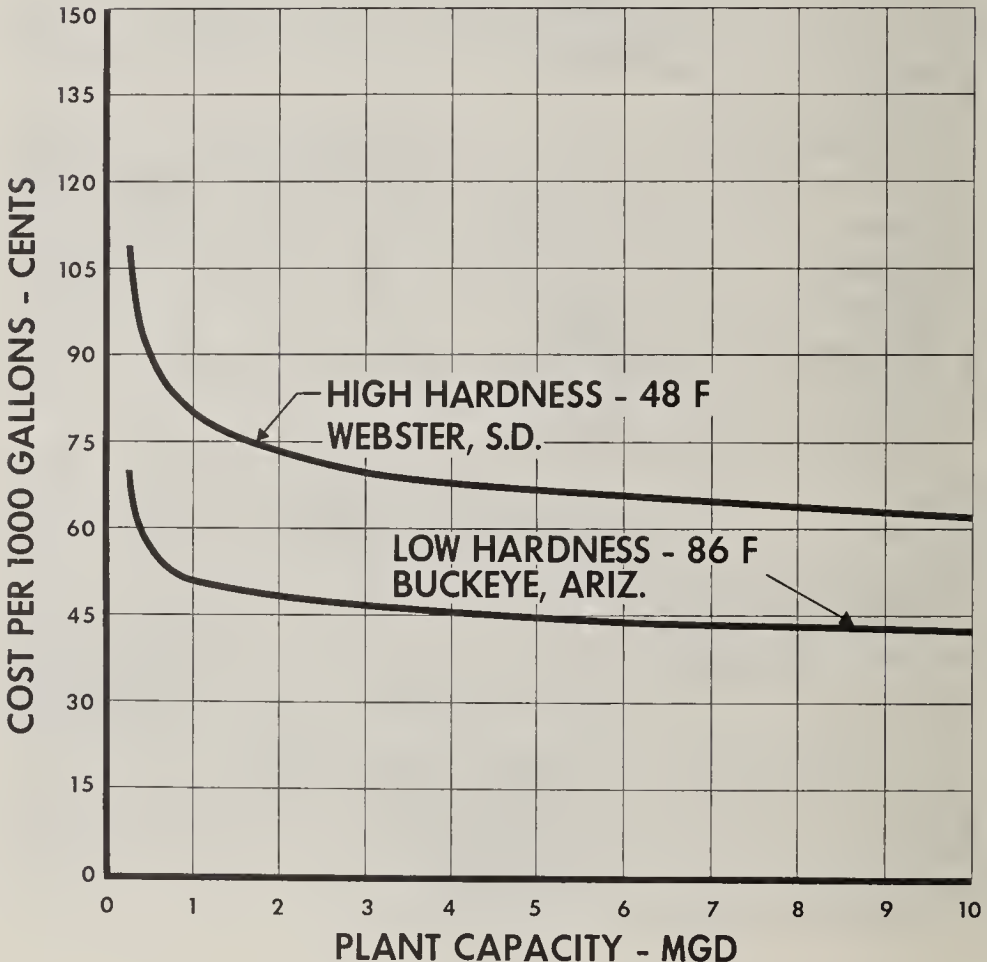
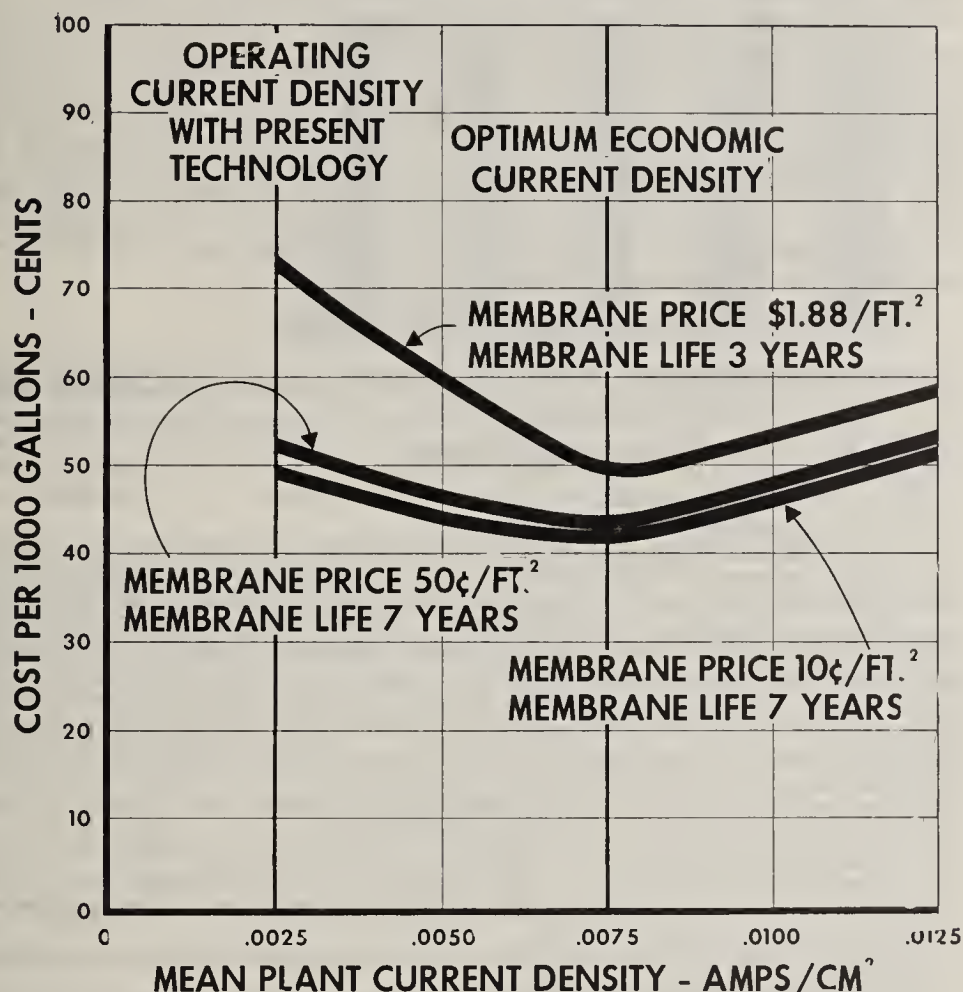


Figure 4

EFFECT OF VARYING MEMBRANE PRICE AND LIFE 1,000,000 GPD ELECTRODIALYSIS PLANT



WATER: WEBSTER, SOUTH DAKOTA
LABOR RATE: \$2.25/HOUR
INTEREST RATE: 5 PER CENT
ELECTRICAL RATE: 10 MILS/KWH

Figure 5

For a 1-million-gallon-per-day plant operating at the present day limiting current density, with a membrane price of \$1.88 per square foot and a service life of 3 years, the cost of water is estimated to be 73 cents per 1,000 gallons. If a membrane cost of 50 cents per square foot and a service life of 7 years is assumed, the cost decreases to 52 cents per 1,000 gallons. If the current density is raised to the economic optimum level, there is a further reduction to 42 cents per 1,000 gallons.

Overall, a reduction in cost of between 40 and 50 percent may be anticipated if we develop means to allow operation of the electrodialysis process at an economic optimum current density and if we develop low cost membranes.

C. Outlook for future advances in electrodialysis conversion technology

With the current state of technology, the economics of electrodialysis conversion limit its application to waters containing less than 4,000 parts per million of dissolved salts. We believe that new knowledge and improvements in technology resulting from an intensive research and development program in electrodialysis will allow us to extend the useful range of electrodialysis to waters of considerably higher salt concentration. In areas where very cheap energy is available, using membranes of high conductivity, high ion-selectivity, low permeability to water, and good mechanical strength and with the development of more sophisticated cell designs than those presently in use, it may be possible to extend the application of electrodialysis conversion techniques to include economically competitive sea water demineralization.

II. TRANSPORT DEPLETION

The "transport depletion" process is a variant of the electrodialysis process and involves the substitution of a nonselective membrane permeable to both cations and anions in place of one of the more expensive ion-selective membranes. The transport depletion cell consists of compartments formed by the alternate arrangement of ion-selective membranes and neutral nonselective membranes. One of the promising features of such a system is the possibility of materially reducing the cost of membranes.

The mechanism of "transport depletion" is very similar to that of electrodialysis. When a voltage is applied across a transport depletion cell, cations (Na^+) move toward the cathode and anions (Cl^-) move toward the anode as they do in electrodialysis. Because of the difference in velocity of the ions in solution and in the membrane, the cations move through the cation permeable membranes faster than they can be supplied to the membrane-solution interface by diffusion. The cations then emerge from the opposite side of the membrane faster than they can diffuse into the solution. After a short time, a concentration gradient across the membrane is established—resulting in the formation of compartments in the cell which are alternately enriched and depleted of salt. The nonselective membrane in the system serves to retard the diffusion of ions from the concentrated cells back into the depleted cells.

The transport depletion process has been demonstrated on a laboratory scale and, as mentioned earlier, there were implications that membrane costs could be reduced, high current densities could be used and polarization and membrane fouling problems could be minimized.

We envision the following exploratory program to assess the economic potential of the transport depletion process:

1. Selection and characterization of membranes to determine optimum properties required.
2. Characterization of the membranes by dynamic methods to investigate polarization effects, efficiency, current consumption and limits of separation efficiency.
3. Evaluation of the data obtained to determine the economic potential of the process and identification of those areas requiring additional development effort.

III. ELECTROGRAVITATIONAL DEPLETION PROCESS

The electrogravitational depletion process is also a variant of the electrodialysis process and involves the use of a series of membranes each of which possess the same charge, either positive or negative, in contrast to the electrodialysis process which uses a series of alternating positively and negatively charged membranes.

In its simplest form, the electrogravitational depletion process system consists of a rectangular container in which are hung sheets of an ion-selective membrane, and a means for applying a direct current in series through the liquid and the membrane sheets. The process is illustrated in figure 6. Because of

ELECTROGRAVITATIONAL TRANSPORT DEPLETION DEMINERALIZED PRODUCT WATER

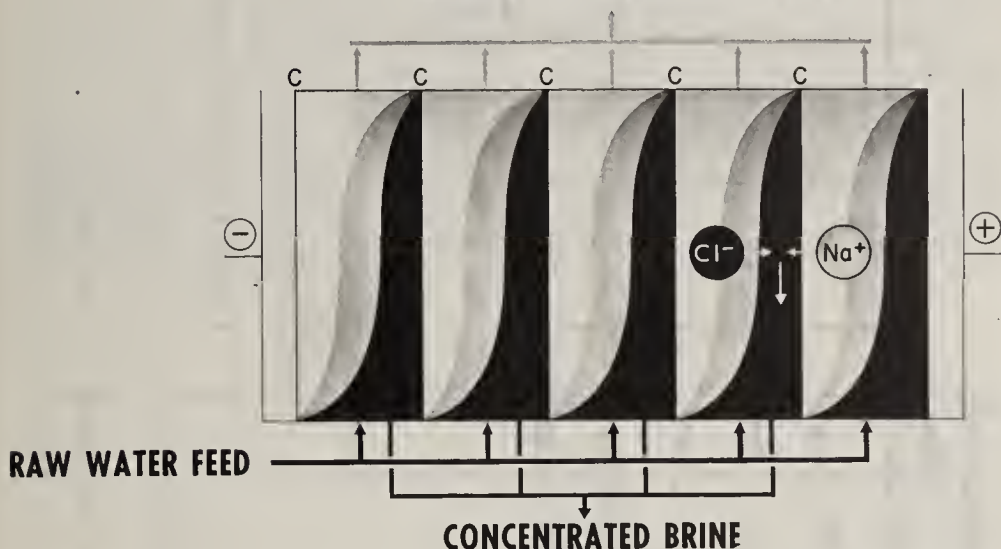


Figure 6

the ion-selective properties of the membranes, the passage of current results in the demineralization of a thin layer of solution adjacent to one side of the membrane. Simultaneously, a concentrated layer of solution is formed adjacent to the other side of the membranes. Since the depleted layer has a higher resistance to the passage of current than the rest of the solution, there is an increase in temperature of the depleted layer. The combined effect of demineralization and electrical heating on solution density establishes a convective flow, in which the demineralized layer rises and the concentrated layer sinks along the membrane surfaces on which they form. The effect is to convert a homogeneous solution into one in which a large difference in concentration exists between the top and bottom. Raw saline water is introduced at the bottom of the unit and desalted product water overflows above the membranes.

The electrogravitational depletion process has already been demonstrated on a laboratory scale and it has been shown that solutions of sodium chloride can be demineralized. However, additional studies are necessary to determine the ultimate economic potential of the process.

We envision an exploratory program to investigate the following system variables:

1. Cell configuration—so that the number, spacing, and height of the membranes can be varied.
2. Membrane selection—membranes to be characterized in terms of porosity, water transfer, and permselectivity to determine optimum properties required.
3. Current density—to be investigated with respect to polarization effects, efficiency, current consumption per unit of product.
4. Hydrodynamic flow—to be varied in order to determine the optimum feed-to-product ratio.
5. Feed water salinity—to be varied to determine the upper limit of separation efficiency with waters up to sea water concentration.

The data obtained in the experimental program will be analyzed to determine the economic potential of the process and will also be used to identify those areas where additional research and development may be necessary to realize the optimum efficiency of the system.

A chronological schedule for the proposed electrodialysis development program is shown in table 1.

TABLE I
ELECTRODIALYSIS DEVELOPMENT PROGRAM SCHEDULE

	1967	1968	1969	1970	1971	1972
<u>Pilot Plants</u>						
Initial Low Salinity, High Hardness Water, Pilot Plant; 25-50,000 gpd	Construct	Test				
Improved Low Salinity, High Hardness Water, Pilot Plant; 25-50,000 gpd	Construct	Test				
Initial High Salinity, Low Hardness Water, Pilot Plant; 25-50,000 gpd	Construct	Test				
Improved High Salinity, Low Hardness Water Pilot Plant; 25-50,000 gpd	Construct	Test				
Initial High Salinity; High Hardness Water Pilot Plant; 25-50,000 gpd	Construct	Test				
Improved High Salinity; High Hardness Water Pilot Plant; 25-50,000 gpd	Construct	Test				
<u>Test Bed Plants</u>						
Test Bed Plant; Low Salinity, High Hardness Water 250-500,000 gpd						
Test Bed Plant; High Salinity, Low Hardness Water; 250-500,000 gpd						
Test Bed Plant; High Salinity, High Hardness Water; 250-500,000 gpd						
Membrane Development						
Feedwater Pretreatment Studies; Application to Polluted Waters and Acid Mine Waters						

IV. REVERSE OSMOSIS

During the 1950's, the Office of Saline Water supported pioneering research at the University of Florida where it was demonstrated, for the first time, that it is possible to effectively desalt sea water by reverse osmosis. This research, and that subsequently conducted at the University of California in Los Angeles, led to a quickening of research and development activity over the last 3 years which has brought this new process into national prominence as a most promising method of desalination.

The principles of the process and the origin of the term "reverse osmosis" are illustrated in figure 7. If a saline solution is separated from pure water by a semipermeable membrane (one which permits the passage of water but prevents the passage of salt), pure water will flow spontaneously into the saline solution with the necessary driving force being provided by the difference in salt concentration between the two solutions. This flow will continue until an equilibrium is established. That is, until the hydrostatic pressure on the salt solution is just sufficient to prevent the further flow of pure water into the saline water chamber. The movement of pure water into the saline water is called osmosis, and the pressure at which the flow of pure water ceases is known as the equilibrium osmotic pressure of the saline solution.

REVERSE OSMOSIS PROCESS

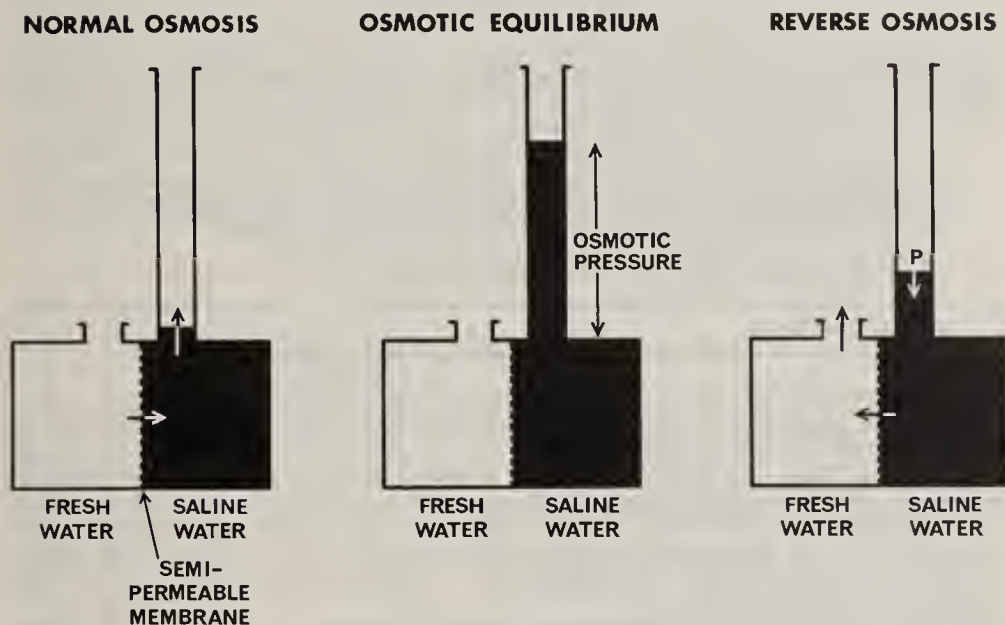


Figure 7

The normal process of osmosis can be reversed if sufficient pressure is applied to the saline solution to overcome the osmotic pressure. Application of a pressure in excess of the osmotic pressure will cause pure water to flow out of the saline solution in a direction opposite to the osmotic flow, hence, the term "reverse osmosis." The driving potential in this reverse case is pressure while in normal osmosis, the driving potential is the difference in salt concentrations between the two solutions.

This principle can be readily translated into a conversion process assuming that appropriate membranes are available. The essential features of a reverse osmosis desalination system are illustrated in figure 8. Feed water is pumped to a pressure in excess of its osmotic pressure and passed through a separation unit which contains semipermeable membranes. A portion of the water permeates the membranes and is collected as desalinated water at atmospheric pressure on the other side of the membrane. The concentrated brine, still at essentially its entering pressure, is passed through a recovery turbine to conserve its contained energy, and discarded.

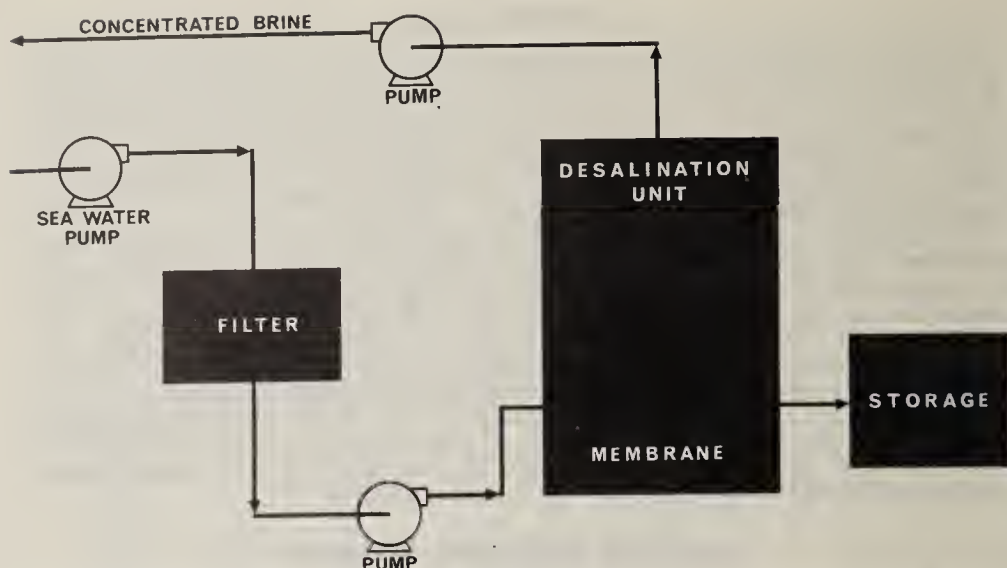


Figure 8

Research on the reverse osmosis principle was encouraged initially, and continued to be encouraged, by the promise this process holds for outstanding economy in the conversion of saline waters. Advantages include the following:

- (1) Low energy requirements. No phase change is involved which inherently makes for a lower thermodynamic energy requirement and tends to simplify the operations. This is in contrast to the distillation, freezing, and hydrate processes where phase changes are necessary.
- (2) Simplicity of the system with respect to equipment.
- (3) The only energy input is electrical energy.
- (4) Normal temperature operation resulting in mineral corrosion and scaling problems.
- (5) General applicability to both sea and brackish waters.

A. Membrane limitations: Potential areas of improvement

From the beginning, it was evident that successful and economic application of the reverse osmosis process depended on a satisfactory membrane. A reverse osmosis membrane, in addition to having adequate life and reasonable cost, must possess the following properties: (1) Be selective enough to permit the passage of water from the saline to the fresh side with low enough salt content to be potable; and (2) be porous enough to pass this water at a high rate under reasonable overpressures. No membranes of this nature existed when the process was first proposed.

In 1953, with the encouragement and financial support of the Office of Saline Water, the initial research program to find a semipermeable membrane for strong electrolytes was undertaken at the University of Florida by Dr. C. E. Reid. The work resulted in the discovery of the salt rejection properties of cellulose acetate and the demonstration that the purification of sea water by this method is technically feasible. However, that work was limited to commercially available films with extremely low water transmission ratio and it was clear that additional membrane development was required.

Following the work by Reid at the University of Florida, the Office of Saline Water supported research efforts which attempted to analyze the mechanism of membrane functions with the ultimate objective of obtaining a membrane with the high water transmission rates that would be required for a practical reverse osmosis process. Other investigators outside of the Office of Saline Water program also continued to explore the membrane problem. Among these was Dr. S. Loeb, of the University of California, who, in 1960, developed a technique for the fabrication of cellulose acetate membranes which converted sea water to fresh water at suitable flux rates. Using $\text{Mg}(\text{ClO}_4)_2$ to modify the cellulose acetate membrane, Loeb obtained transmission rates of 5 to 11 gallons per square

foot of membrane surface per day. These rates exceeded the flux rates obtained at Florida by 50- to 100-fold. On a laboratory scale of production, membranes are routinely fabricated which permit product water flows of 5 to 10 gallons per day per square foot with salt rejections of 95 to 99 percent, and even higher flows for treatment of brackish water where a lesser degree of salt removal is required to produce potable water.

Currently, it is estimated that about two-thirds of the cost of water produced by reverse osmosis represents the cost of membranes and their replacement. Accordingly, we propose to increase our emphasis on membrane research and development.

Membrane replacement costs can be reduced sharply by (1) increasing the potable water flux through the membrane; (2) reducing the unit cost of the membrane; and (3) increasing membrane life.

With respect to item (3), membrane life, the deterioration of cellulose acetate membranes with time had been viewed as a serious limitation of their ultimate usefulness; but recent work has shown that the lifetime behavior can be markedly improved through pH adjustment of the feed water. Figure 9 shows the results of some lifetime experiments performed at the General Atomic Division of General Dynamics Corp. under an Office of Saline Water contract. Here, the salt permeation constant, a measure of the rate at which salt leaks through the membrane, is shown as a function of time in test. The two experiments in which pH adjustment is being used are still in progress, and measurable membrane deterioration has yet to be observed.

The membrane material being produced at the present time gives salt rejections per pass of 96 to 99 percent when operating in the 1,000 to 1,500 pounds per square inch range. Thus, with sea water feed, potable water (500 parts per million) will not be produced in one pass except under optimum conditions. This,

LIFETIME OF CELLULOSE ACETATE MEMBRANES

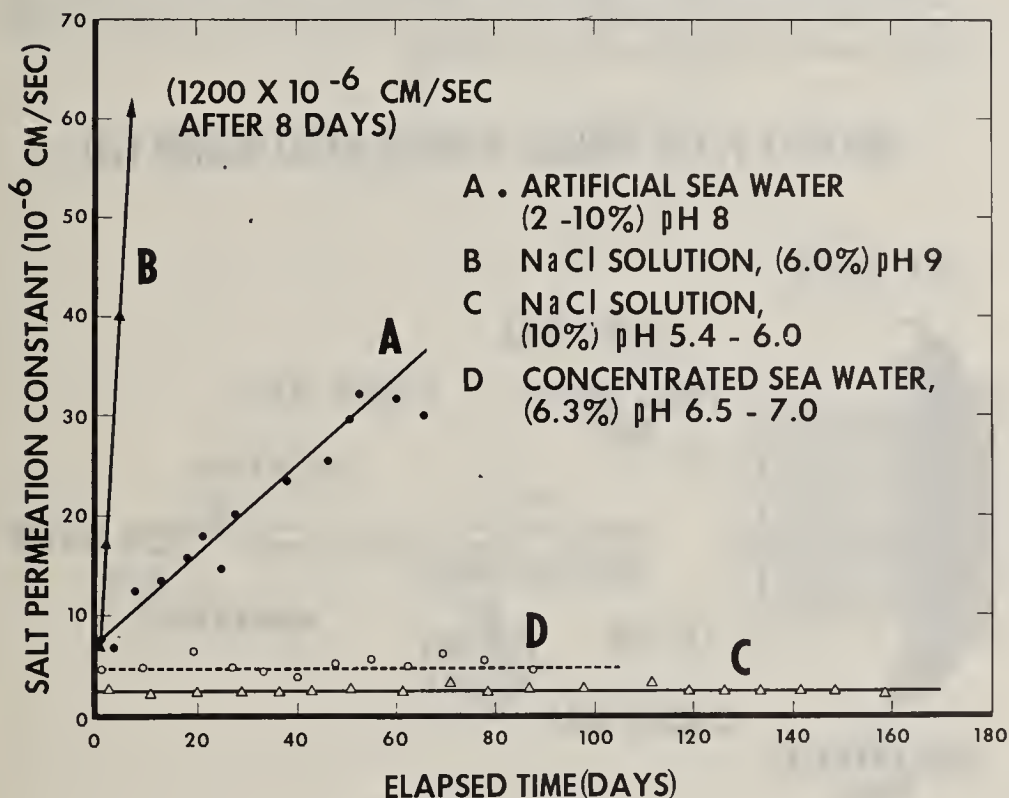


Figure 9

too, had been considered to be a serious limitation of the ultimate usefulness of the process. However, workers at the Aerojet-General Corp., supported with funds provided by the Office of Saline Water, showed that the salt rejection of cellulose acetate membranes could be maintained at a sufficiently high level to accomplish the conversion of sea water to potable water in a single pass. This was accomplished by the addition of small amounts of polyvinyl methyl ether to the feed water. A better solution would be the development of a higher rejection membrane through membrane research or improved membrane manufacturing techniques.

In our proposed program, we will increase efforts directed toward: (1) Improvement of cellulose acetate membranes; (2) alternative membranes which combine suitable permeation properties with greater durability; and (3) problems of membrane production on a commercial scale.

B. System design and development

During the past 3 years, the Office of Saline Water has accelerated its development effort on the reverse osmosis process. Progress made during that time has convinced us that the decision to emphasize reverse osmosis is a prudent one and that the process can be reduced to large-scale practice during the next few years if a vigorous development program is implemented. Parametric studies and conceptual design studies invariably show reverse osmosis plants to have much lower energy requirements than the typical energy requirements of distillation plants. For example, the best evaporative conversion plants in operation consume approximately 30 times the minimum theoretical energy required for the separation of salt from water, whereas the reverse osmosis process consumes approximately 7 to 9 times the theoretical energy.

This low energy requirement was shown to exist on qualitative grounds before any of the current work on reverse osmosis was initiated. It is the low energy requirement that is probably the most attractive feature of the process.

Work now in progress and which we propose to accelerate is aimed to a considerable extent at determining and minimizing capital costs.

At the present time, the Office of Saline Water has two promising design concepts under investigation, the approach taken at Aerojet-General Corp. which is based on a plate-and-frame concept as shown in figure 9a, and the approach taken at General Atomic Division of General Dynamics Corp. which is based on a spiral modular concept as shown in figure 10.

MULTIPLE PLATE REVERSE OSMOSIS DESALINATION CELL

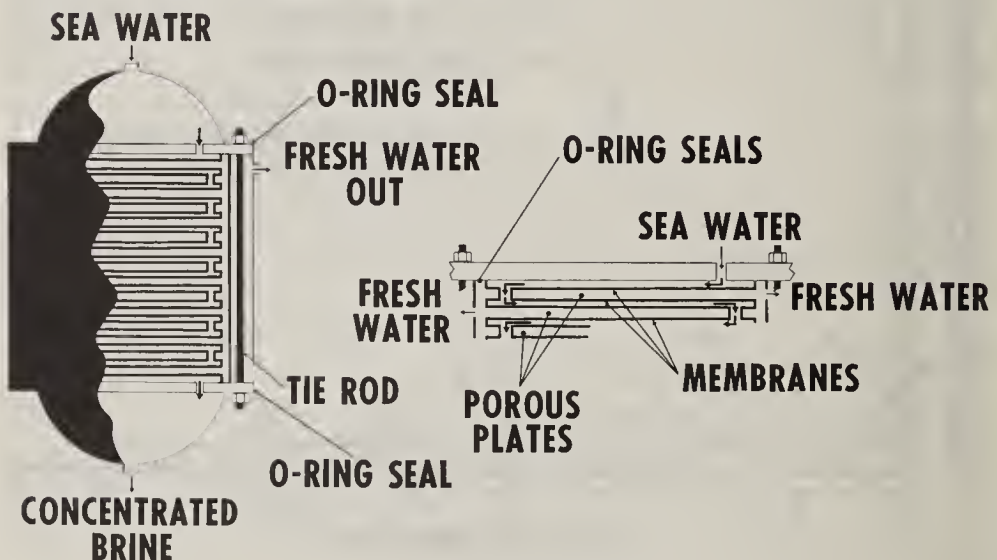


Figure 9a

REVERSE OSMOSIS SPIRAL MEMBRANE MODULE

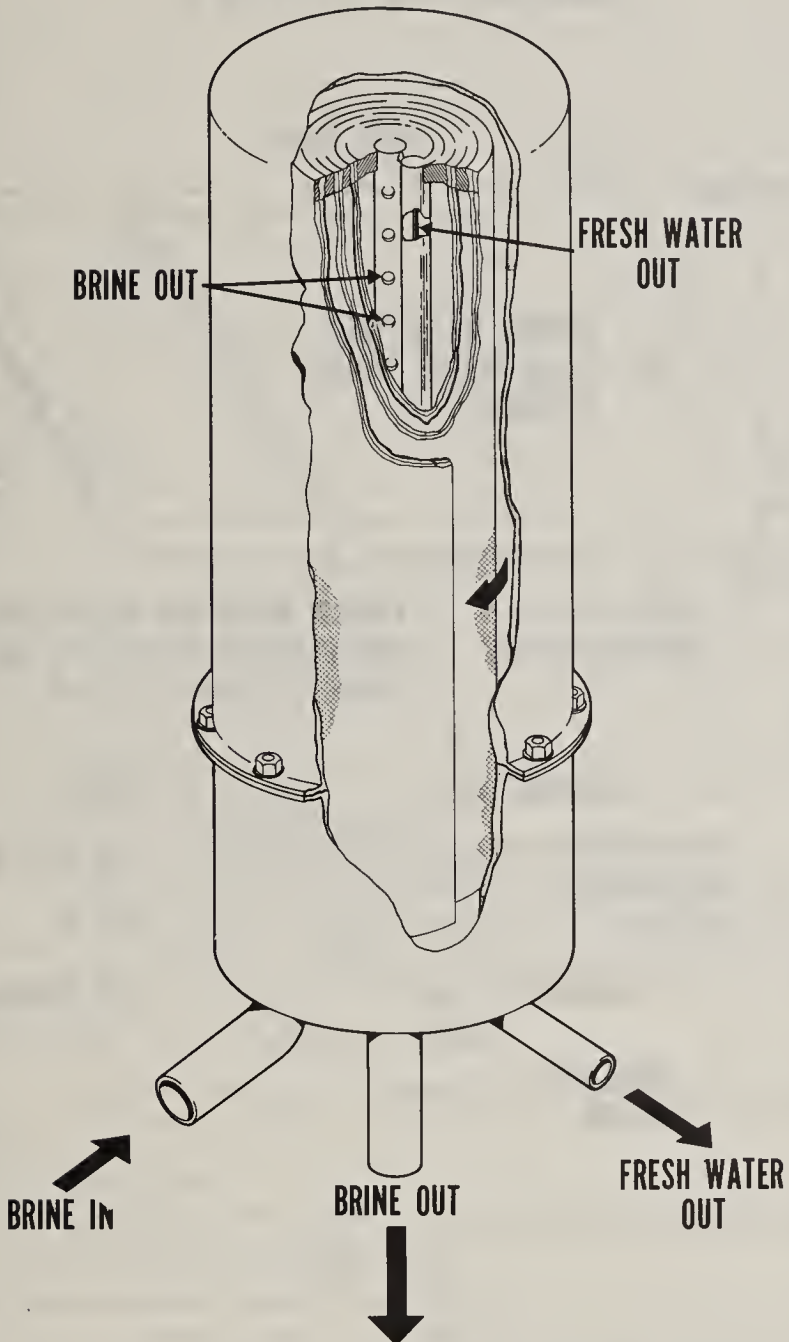


Figure 10

REVERSE OSMOSIS DETAIL OF SPIRAL MEMBRANE CONCEPT

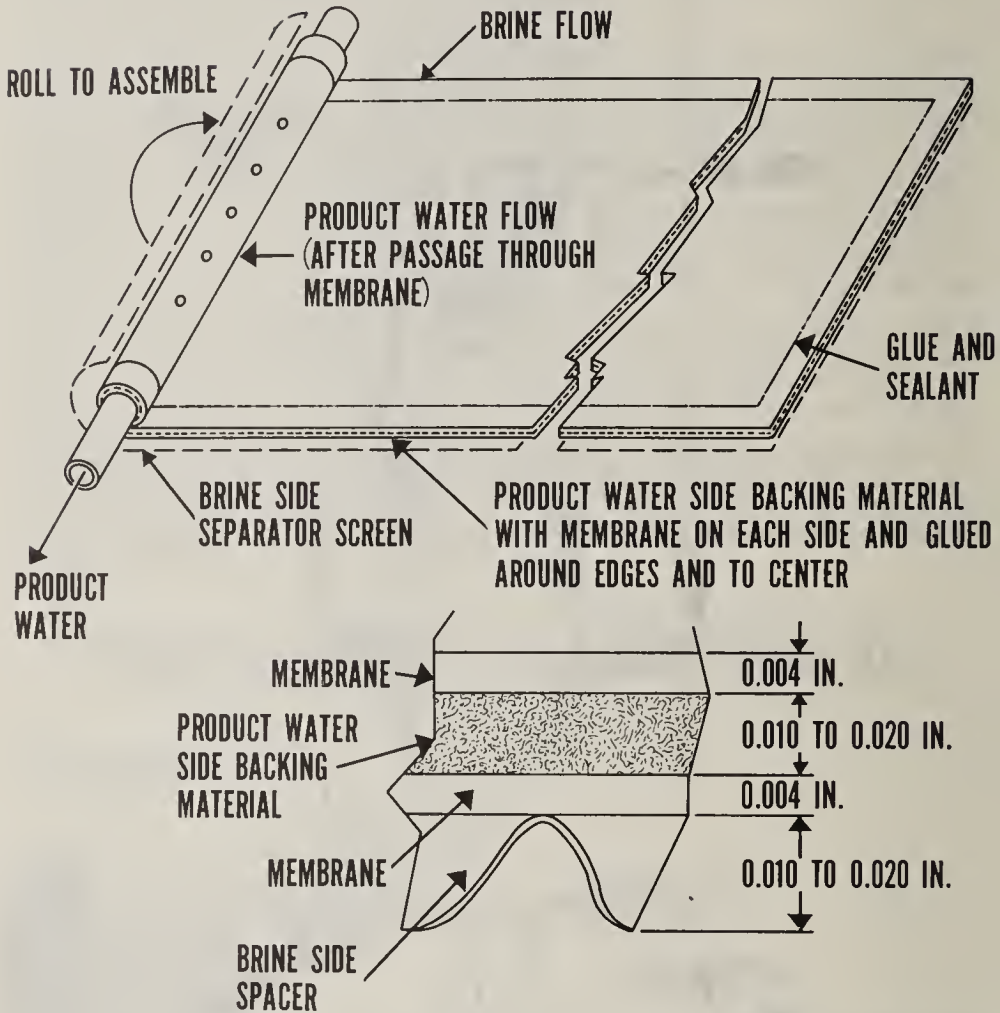


Figure 10a

The most advanced of the two designs on the basis of reduction to practice is the plate-and-frame concept. A 1,000-gallon-per-day module has been tested on both brackish and sea water with extremely encouraging results. The spiral modular concept has been successfully tested on brackish water and work is currently in progress to adapt the design for sea-water application.

C. Cost factors in reverse osmosis systems

The reverse osmosis process is still in an embryonic stage of development. There are no pilot or demonstration plants in existence capable of producing definitive cost data. However, in the course of the research program, continuous economic analysis has been necessary to evaluate equipment designs, materials, and membrane improvements, particularly as those variables affect the cost of future plants. Based on that experience, estimates have been made which show that the cost of converting sea water by reverse osmosis should be less than \$1 per 1,000 gallons and for brackish water less than \$0.50 per 1,000 gallons.

Some of the factors affecting the cost and the improvements already achieved are more indicative of economic progress in reverse osmosis than generalized dollars and cents estimates. The key to the economics of reverse osmosis is the membrane. The life, durability, and cost of fabrication are the important factors. A few years ago the price of a cellulose acetate membrane was estimated at about \$3 per square foot. The question also was raised as to the feasibility of performing economically, in quantity production, the series of steps involved in membrane fabrication. During the past 2 years, it has been shown that membrane fabrication lends itself readily to mechanization and that production of the membrane on a continuous basis is entirely feasible. It has been noted also that the cost of the raw materials in a square foot of cellulose acetate membrane is only a few cents. These experiences lead us to believe that a cost of 25 to 50 cents per square foot of membrane is a realistic goal and attainable with present technology. The problem of building machines for membrane production appears to be one of engineering design and testing, not one of innovation.

The life of service period of a membrane is naturally important in determining the cost of the process. In the beginning there was some question about the validity of the predicted 6-month service life. However, actual operating experience on the 1,000-gallon-per-day test module fully supports this estimate of service life and tests now in progress indicate that membrane lifetime may be lengthened considerably by adjustment of the pH of the feed water.

Higher flux rates would normally be expected to reduce costs and some further improvements are expected in this area. However, the chief economic improvement is not to be expected in higher flux rates alone since fluxes are already comparatively high and a point will be reached where other factors begin to offset the effects of increased fluxes.

The first conceptual design studies made for large-scale reverse osmosis plants showed that the membrane-containing structures accounted for over half of the total equipment costs in those plants. Since that time, design effort has centered on the development of membrane modules which may be installed inside sections of standard-size carbon steel pipe. The modular approach reduces the cost of the pressure vessels to the cost of the pipe and suitable fittings, and makes the contribution of this component less than 25 percent of the total equipment cost.

V. PROGRAM OUTLINE

In order to realize the full potential offered by the reverse osmosis concept, the Office of Saline Water proposed the following engineering and development program:

A. Membrane development

Investigations seeking improvement in the properties of cellulose acetate membranes and the search for alternative membranes with properties superior to cellulose acetate will be accelerated.

B. Module design and module construction techniques

The membrane module is the key component of a reverse osmosis plant. Its properties largely determine operating parameters, and its costs are the greatest source of uncertainty in present cost projections. For this reason, a major program on module development and the development of techniques for manufacturing membrane modules is suggested.

C. Design and construction of two 50,000 gallon-per-day prototype pilot-plant modules

Each of these modules will embody different design features and will serve primarily to test the feasibility of the design and the manufacturing techniques used in fabricating the modules. The design of these plants will be such that they can be used for both brackish and sea-water applications.

D. Design and construction of two 250,000 gallons-per-day test bed plants

These two plants will be specifically designed for operation on brackish water. The operation of the pilot plants, and experimentation with them, would be directed toward the investigation of the validity of the criteria used in designing them and to provide definitive data for engineering design of larger plants.

E. Engineering design of a 1-million-gallon-per-day experimental brackish water test bed module

At this point in the development program, the design showing the best operating performance through the 50,000 and 250,000 gallon-per-day test states will be selected for future development.

F. Construction of the 1-million-per-day experimental brackish water test bed module

G. Operation of the 1-million-gallon-per-day experimental brackish water test bed module

It is expected that during operation, critical areas for plant improvements and cost reductions will become apparent. It is too early to predict just what these areas will be, but an allowance for further development work is included in the suggested program in order to immediately exploit those findings which may lead to significant cost reductions.

H. Sea-water program

Concurrent with the development effort on the brackish-water applications of reverse osmosis, design and test effort to develop an optimum system design for sea-water application of reverse osmosis will also be conducted.

I. Selection of design criteria for sea-water plant

The 50,000 and 250,000 gallons-per-day prototype modules used to obtain test data for the design of the brackish water test bed plant will be modified and adapted for sea-water operation. The data obtained from operation of those prototype modules plus the operating experience gained from the 1-million-gallon-per day test bed brackish water plant will be used to develop the design for a 1-million-gallon-per-day sea water test bed plant.

J. Study of feed water composition variables on membranes and plant performance

The chemical composition of sea water throughout the world is relatively constant. Except in the vicinity of harbors and river outlets where organic pollution may be encountered we do not foresee major problems arising which would lead to the need for expensive preconditioning of feed water. Brackish water, however, presents us with a number of potential problems. The composition of brackish water varies widely among different sources and is even known to vary in different wells in the same aquifer. In brackish water, one may encounter heavy metals at a much higher concentration than in sea water, suspended matter such as colloidal clay, organic matter, sulfur and other materials which may adversely affect reverse osmosis membranes. We propose to determine the effect of those contaminants on membrane performance and to develop means for their control in order to insure optimum membrane performance.

A chronological schedule for the proposed reverse osmosis development program is shown in table 2. It calls for startup of a 1-million-gallon-per-day brackish water test bed plant in 1972. We believe that goal is attainable if funds are made available for the program.

TABLE II
REVERSE OSMOSIS DEVELOPMENT PROGRAM SCHEDULE

	1966	1967	1968	1969	1970	1971	1972	1973
Initial 250,000 gpd Brackish Water Test Bed Plant								
50,000 gpd Pilot Unit	Construct - Test ->							
250,000 gpd Test Bed Plant (Brackish)	Design & Construct	Design & Construct	Design & Construct	Design & Construct	Design & Construct	Design & Construct	Design & Construct	Design & Construct
Improved 250,000 gpd Brackish Water Test Bed Plant								
50,000 gpd Pilot Plant		Construct	Construct	Construct	Construct	Construct	Construct	Construct
250,000 gpd Test Bed Plant								
1,000,000 gpd Brackish Water Test Bed Plant								
Sea Water Test Bed Plant								
50,000 gpd pilot plant modified and adapted to sea water								
250,000 Test Bed Plant for sea water								
1,000,000 gpd Test Bed Sea Water Plant								
Studies in Membrane Development and Manufacturing Techniques								
Includes operation of small test units to determine life, durability, and effects of water quality								
Studies of Feedwater Preconditioning Treatment								

VI. BRACKISH WATER TEST FACILITY

The proposed membrane program deals primarily with engineering development and much of the program involves construction, testing, and operation of bench scale equipment, pilot plant modules and complete experimental test bed plants.

The membrane processes hold most promise for initial application to the conversion of low and moderately saline waters. For this reason, the first goal in the membrane program will be the development of the most efficient and economical process for the conversion of inland brackish water supplies.

To attain that goal, it will be necessary to test proposed processes and system designs and to obtain operating and economic data for each of the advanced design concepts selected for intensive development. Since processes and designs will be competing with each other, it will be necessary that the test modules and the processes embodied in them be operated under standard conditions.

To insure that standard conditions are provided, we are requesting funds for the establishment of an inland brackish water test site to provide adequate facilities for the simultaneous operation of between 6 and 12 pilot and test bed plants. The daily feed water requirements for those plants will vary between 50,000 and 2 million gallons per day and facilities will need to be provided to handle the disposal of up to 1 million gallons per day of brine.

Senator ANDERSON. I have one more witness who has asked to be heard, Mr. Harold R. Hay.

Please come forward, sir.

STATEMENT OF HAROLD R. HAY, MENLO PARK, CALIF.

Mr. HAY. Mr. Chairman and members of this committee, I appreciate the opportunity to come before your committee today.

Several members of this committee yesterday expressed concern for the plight of individual ranchers who would be satisfied with considerably less than the millions of gallons per day of water produced by the five principal desalination processes so far discussed at this hearing. These ranchers would be satisfied with a few thousands of gallons for their cattle and, at times, a few gallons for themselves.

Though I represent only myself in making this presentation, I feel as though I were speaking—with some familiarity—for tens of thousands of ranchers and for millions of the world's poor. Also, because, to the best of my knowledge, no one else has referred to it, I should particularly like to discuss a desalination process which has much promise for the individual need but which has lost support in the battle for Government research funds.

I would like to read briefly from the 1962 publication of the National Research Council titled "Desalination Research and the Water Problem."

As was emphasized by the President (John F. Kennedy) * * * the opportunity of providing developing countries in arid regions with saline water conversion facilities as part of our foreign aid program is most appealing. Supplies of good water can mean more, and perhaps cost less, than many other things we might do for peoples whose living standards are depressed by lack of water. A recent congressional report comments as follows: "To the United States, which has a vital stake in seeking their good will and in cementing pro-Western attitudes of peoples in underdeveloped lands, the means for providing the know-how and equipment for the production of pure water could be a telling item in international relations—to say nothing of economic factors." * * * Cheap solar stills will be more appropriate than large units requiring a great deal of electric power, the reverse of the situation in this country.

But before discussing solar stills, I must, with particular instances in mind, take exception to a statement made here yesterday, by a corporation executive to the general effect that nothing of use to him had been gained from the many research contracts issued to others. Unquestionably, his research men, just as I, look for and use that seed of new knowledge which is present in any competent research dealing with the subject of water.

Since large corporations have felt it helpful to this committee to explain their background and qualifications, I am likewise motivated to do so as an individual. Large corporations have profited to the extent of over a million dollars per year through a wood preservation process I developed to success. A second development of mine is also used throughout the world and deals with water purification but not with desalination. In addition to conducting research for large companies in the United States, I have been sent abroad by the United States, by the United Nations, by one of our largest research institutions, and by a private company. During this foreign experience, I have lived in India, Colombia, Venezuela, and Sweden. I have seen the parched and hungry whom I cannot forget. It is with them in mind that I suggest this committee's attention to the requirements of individuals as well as of cities. Some of the parched individuals also exist in the United States in conditions similar to a disaster area.

It seems ironic to suggest that if one American were to be lost on a desert, whether it be in my West or in a foreign land, immediate assistance would be given by our Government at considerable expense. Abroad, an American consul would initiate a search, call on the nearest military agency for search planes, ask for a helicopter if the man were spotted, and put him in a nearby military hospital if necessary because of the ravages of thirst. This is commendable care of that individual. But today it is seemingly impossible to get that much money from the prime Government source to investigate solar distillation processes which could benefit millions of individuals.

While much wasteful research has been done, in my opinion, some of this research has provided me with data for designing novel solar stills which may be yet lower the cost and increase the efficiency to the point of becoming a breakthrough.

Recently, the Church World Service installed a solar still in Greece and together with the Greek Government discussed building such solar stills on 100 to 200 islands. The other processes discussed at this hearing would be totally uneconomical for these small parched islands. The first still in Greece was built according to plans from one of our largest corporations, which had collaborated with the Office of Saline Water. Yet that still has encountered problems and I am now advised that major design changes are being made to test one of several new principles which I have originated without help from others.

This causes me to recall that creative research is the essence of breakthroughs and I do not believe that such research must come from large corporations, from large research institutes, or from large Government agencies. These are not the sources of creativity though they may be the best means for fulfillment. Creativity surges from the individual within such organizations and it can just as easily, or perhaps more easily, come from the creative individual who is not within large organizations. The individual does not need, and perhaps should

not have, much funds if he is to confine his creativity to the economic level of the thirsty.

May I suggest that this committee consider the reestablishment of support for solar distillation processes. And incidentally, solar processes are the first nuclear processes that have ever been developed.

Today, the door is shut on new ideas. If as little as 5 percent, or even 1 percent, of Government funds designated for desalination were specifically earmarked for solar designs, with the big five processes getting the rest, there would be sound encouragement for new and creative thinking in the solar energy area. I would propose a restriction, however, that this precious drop of sustaining funds should not be used for rehashing old ideas, and that new ideas should not be evaluated by those whose previous Government grants have proved unproductive. Rather, I would propose that the individual should find a receptively open door, if he can show that his work will cost less and has equal promise when impartially compared with that of large research organizations which long ago had to give up the concept of collective creativity by a brain trust. I would further ask that in individualistic America an open door be maintained for simple processes but that regard be given to the quotation, "Oversimplification is the evil of small minds."

It is not true that creativity, research, and invention today are beyond the means of the individual in all fields; it is not true that solar distillation is an overworked, washed-out area of no promise; it is not true that the United States should think solely in terms of desalination plants with capacities of at least a million gallons per day, or as we have just heard, 300 million gallons per day. Australia is extensively studying solar stills—as is Israel. In the United States, we too have arid areas of marginal water supply where an additional bit of fresh water could make all the difference.

The poor we shall always have with us—and they need water. The sun we shall always have with us—and it takes water away. But with the help of this committee, and with some brain stretching by creative individuals, the sun can be made to give back enough of that water to make this a better world for many. Solar stills must be made cheaper. Each year the cost of plastics, so important to modern solar stills, is being reduced, their properties improved, and their contribution to a breakthrough in solar distillation more certain. Solar stills in no way compete with those other areas of desalination research aimed at providing millions of gallons of water per day. Research on solar stills will continue though it has recently encountered rough going. There is a need—improvements will eventually meet the need. If this committee will help, there is the certainty of shortening the time required and/or enlarging the benefits resulting to those whose only hope lies in solar distillation.

Thank you, Mr. Chairman.

Senator ANDERSON. Mr. Hay, thank you for an interesting statement. I do appreciate your emphasis on the fact that individuals need some attention in this whole subject. I thank you for it.

Mr. HAY. Thank you kindly.

Senator ANDERSON. Mr. Joseph F. Sinnott, president of the San Diego Gas & Electric Co., submitted the following statement and asked that it be printed in the record.

(The statement referred to follows:)

STATEMENT OF SAN DIEGO GAS & ELECTRIC CO.'S EXPERIENCES WITH SEA WATER CONVERSION

The company's interest and active participation in the field of sea water conversion and evaporator operation dates back many years. Due to the geographic location of the company's service territory, the rapid population growth (which began about 1940) and the limited natural fresh water supply, it became obvious to management that research and development in the art of sea water conversion was most essential.

With concern for the economic well-being of the area we serve, and in the overall public interest, the company's engineers have, for many years, been actively engaged in studies concerning projects designed to supply both natural fresh water and converted sea water at the most economical level.

With the passing of time, our interest in the field of sea water conversion has greatly accelerated. In addition to our work in connection with the multistage flash evaporator, we have been closely associated with a reverse osmosis demonstration plant. We are also working with a third process not yet ready for announcement.

During the period when plans were being formulated for the first Point Loma plant, our engineers worked with those who were responsible for the location and design selection. We followed with interest the development and operation of the Point Loma unit.

A very brief summary of the company's more recent activities in the field of sea water conversion is as follows:

1. South Bay generating unit No. 2 at Chula Vista, Calif., provided our first flash evaporator to supply water for boiler makeup. This was placed in operation in 1962. This is the second such evaporator in the United States for the supply of boiler makeup.

2. To gain further experience and to bring about further improvements in design, the second such flash evaporator was installed with generating unit No. 3 in 1964.

3. Our work in the field of multistage evaporators resulted in a firm proposal which the company made in August of 1963. At that time we announced to the local water agencies our readiness to install a 25-million-gallon-per-day multistage flash evaporator which would be supplied with "bleed" steam from our South Bay generating unit No. 2.

Some additional details of this offer may be of interest. While South Bay unit No. 2 was not designed specifically as a generating unit which would also serve a 25-million-gallon-per-day flash evaporator, our engineers noted that the steam quality and quantity at the crossover between the intermediate and low-pressure turbines approached very nearly the ideal situation.

After some detailed studies by our engineers, Westinghouse Corp., was invited to submit a proposal for a 25-million-gallon-per-day sea water flash evaporator to serve with South Bay unit No. 2. Following a review of the work performed by company engineers, the Westinghouse Corp. submitted a firm "turn key" proposal to provide the evaporator plant together with all necessary auxiliary equipment including a product delivery pump designed to operate at a discharge head of 100 feet.

It should be noted that the generating unit involved is rated at 150,000 kilowatts, the average fuel cost at that time was 35.9 cents per million British thermal units. The conversion plant was charged with its full share of power (both electric and steam), operation, maintenance and fixed charges (based on ownership by one or more of the local water agencies). The final cost of the converted water was set at 41.1 cents per 1,000 gallons, a firm price.

For a more detailed review of the proposal, we have attached an analysis which was formulated after presentation and evaluation by those concerned.

4. After a long period of study and laboratory development, conducted by Dr. Glenn G. Havens of Havens Industries, our company joined Dr. Havens to make possible a reverse osmosis pilot plant. In April of 1964, after a successful period of operation, we joined Dr. Havens in a public announcement at which time the demonstration plant was shown to leaders in Government, industry and business.

Credit for the conversion element goes to Dr. Havens who has now been joined by the Richfield Corp. We are continuing our work with Dr. Havens and our serious interest in what appears to be the most promising development of the time in sea water conversion.

5. On December 9, 1964, in a letter to Secretary Udall, company president J. F. Sinnott offered the U.S. Department of Interior a unique opportunity. This offer was made in the public interest to assist with the proposed West Coast Sea Water Conversion Test Facility. Due to the design and location of our South Bay powerplant, we believe the proposed facility can be installed and operated at an economical level not possible at any other site. In addition, there is a ready market for any product water plus multiple uses for the water in industry, agriculture and for domestic purposes.

Other uses are possible in the immediate vicinity. There are some valuable domestic water wells nearby which have been rendered useless by reason of salt water intrusion. These wells may be rehabilitated through a process of "charging" with converted sea water. Also, a nearby salt works would no doubt benefit if the discharged brine were made available for their evaporation ponds.

6. San Diego Gas & Electric Co. joined with the city of Los Angeles Department of Water and Power and Southern California Edison Co., in preparing and presenting a proposal to the metropolitan water district. This proposal, presented on April 8, 1965, opens the way to build and operate a nuclear power-plant-sea water conversion complex. The output of the sea water conversion plant would be 150 million gallons per day.

7. While details cannot be announced at this time, the company is currently planning with a prominent firm the building and operation of a second reverse osmosis prototype plant.

8. As a member of the Edison Electric Institute, the company is actively participating in a research project to evaluate sea water conversion and water supply.

Assuming for the moment that the final results, brought forth by research and development, indicate clearly that multistage flash distillation will be the most economical means to convert sea water, it does not necessarily follow that a dual-purpose plant will be employed in every case. To determine the proper heat source, it will be necessary to consider in detail the requirements for water and electric energy and coordinate the design of both elements of plant. Peaks and valleys of demand, the storage of water, interruptibility of waterplant and many other factors loom large as we approach the time when a dual-purpose plant must be considered and built.

While it is too early to predict with any real assurance, our work with the reverse osmosis process indicates that this method may have greater potential than formerly believed possible. The simplicity of design, the low power consumption and the successful experience with the membrane have been very encouraging. It is possible that reverse osmosis may indeed replace flash evaporation as the most practical and economical process.

The foregoing is just a small part of that which makes the proposed test facility "a must." Not until this facility has had time to "prove" many concepts and designs will it be safe or prudent to proceed with a plant of any magnitude.

EVALUATION OF DUAL-PURPOSE SEA WATER CONVERSION PLANTS

In August of 1963 the San Diego Gas & Electric Co. proposed to the water agencies in its service territory that the company could modify its South Bay generating unit 2 to supply sufficient steam to operate a 25 million gallons per day sea water conversion plant. The company offered to cooperate with any of the agencies which might wish to construct and operate the waterplant.

Estimated water costs.

Estimated costs for producing water with this dual-purpose plant arrangement were as follows:

	<i>Cents</i> <i>1,000 gallons</i>
Fixed charges (waterplant only \$13,850,000 at 6-percent fixed charge rate) _ _	10.1
Operation and maintenance _ _ _ _ _	1.8
Chemicals _ _ _ _ _	3.9
Electric energy and waterplant pumping _ _ _ _ _	6.8
Equivalent cost of steam to waterplant _ _ _ _ _	18.5
Total cost _ _ _ _ _	41.1

The company was confident that this cost estimate was realistic in that the three principal items were known with a good degree of certainty. The company had in hand a proposal from Westinghouse Electric Corp. for turnkey construction of the 25 million gallons per day multistage flash evaporator unit. Cost of

electric energy and steam to the waterplant was based on studies of an existing electric utility system and a specific steam-electric generating unit. The economic evaluation considered the effect of steam extraction for the waterplant upon electric system fuel costs, taking into account the adverse effect upon equal incremental cost dispatching of all generating units on the system.

Contemplated mode of operation

The generating unit selected has a net electrical capability of 150,000 kilowatts with steam conditions of 2,000 pounds per square inch, 1,000° F. The flash evaporator unit was to operate with an outlet brine heater temperature of 250° F.

Steam to the waterplant was to be supplied by extraction from the crossover pipe between the intermediate-pressure and low-pressure turbines. Sufficient steam flow was to be maintained through the low-pressure turbine to prevent low-pressure turbine overheating. The extraction steam pressure would be 50 pounds per square inch absolute.

Cost estimates were made on the basis of 90 percent load factor operation of the water-conversion plant. With the waterplant producing full output, the net output of the generating unit would be reduced to 86 megawatts. In addition to reduced output because of steam extraction, 10.2 megawatts of this reduction was due to auxiliary power required for waterplant pumping. The contemplated method of operation was: (1) operate boiler continuously at full load steam output; (2) turbine-generator operated with control valves wide open and a net electrical output of 86 megawatts.

With the foregoing mode of operation the unit is capable of providing 74 megawatts of valuable spinning reserve capacity, assuming the waterplant operation could be interrupted. The cost estimate was based on an interruptible mode of operation and, hence, no capacity charge for the power-generating unit was assigned to water cost. It was anticipated that interruptions would occur no more than four or five times per year and, normally, would be of short duration. The costs were based on an average fuel cost of 35.9 cents per mm.B.t.u.

Cost determination of heat supplied to waterplant

The cost of steam supplied to the waterplant was based upon the cost of fuel required for generation on other generating units as replacement for energy because of the reduced electrical output of South Bay 2. Since all of the system's generating units are dispatched on an equal incremental cost basis, this required determination of the effect on system incremental generating cost of the loss of output from South Bay 2. In the early years of operation, while South Bay unit 2 would be one of the most efficient generating units on the company's system, the system incremental costs are increased by reason of unavailable generation from unit 2. In later years, the system incremental fuel cost is increased because South Bay unit 2 must be maintained at 86-megawatt output, when on an equal incremental cost-dispatching basis it would otherwise be operated at lower output or taken out of service altogether.

No study was made of the effect of operating the boiler at less than full output to produce less than 86 megawatts-electric, and 25 million gallons per day of water. It is possible that a more extensive study might disclose that the optimum mode of operation would be with variable boiler output. This type of optimization would require extensive computer simulation studies to produce valid results.

Response from local water agencies

After study of the company's proposal, the water agencies advised the company that the estimated cost of 41 cents per 1,000 gallons was not currently attractive to them since their cost of water was 7 cents per 1,000 gallons. Nevertheless, as discussions were held between the company and the water agencies, a number of rather interesting operational aspects of the proposed dual-purpose plant became apparent:

1. There is great concern on the part of the water agencies as far as the introduction of pure, unbuffered water into this distribution mains. Various schemes for blending the proposed 25 million gallons per day output with Colorado River water were discussed. The daily and seasonal flow rate in the city of San Diego distribution system varies widely. So widely, in fact, that it appeared impractical to introduce the waterplant output directly into the distribution system (if the plant were to be operated at 90 percent load

factor). This meant that additional pumping costs would be incurred to pump the product water to reservoirs and treatment plants for blending.

2. Since water supply projects have traditionally required long leadtimes for design and construction, the availability of an offer to provide a site and steam supply for a waterplant provides the local water agencies with a degree of insurance should any of the long-term water supply contracts fail to materialize, or should water demands increase at a rate greater than predicted.

3. Evaporation losses from storage reservoirs in the area are a very significant item amounting to several hundred thousand dollars per year. It appeared that the use of the waterplant for supplying seasonal peakload requirements to forestall investment in additional reservoirs, with their attendant evaporation losses, should be further investigated.

4. There would be some benefit to the water users from diluting the high mineral content Colorado River water with relatively pure water, if the dilution rate can be maintained within reasonably close limits. Wide variations in water quality, even though all variations are in the direction of greater purity, are considered undesirable.

5. The water agencies are interested in a water conversion plant since it could provide water during emergencies and outages which might occur in the aqueduct systems supplying the area.

S.D.G. & E. conclusions based on August 1963 proposal and subsequent evaluation

In making its economic assessment of the proposed dual-purpose plant, S.D.G. & E. followed the currently accepted practice of assuming high load factor operation of the waterplant. The high-load factor was assumed in order to demonstrate the lowest possible cost of product water. The company is now convinced that economic evaluation of dual-purpose plants, based on arbitrarily assumed high-load-factor operation, has diverted attention from other modes of operation which are potentially more beneficial.

The approach in analyzing dual-purpose plants to date has been that of a "hardware" study rather than a "systems" study. Production of water in a dual-purpose plant requires coordinated design and operation of not just a powerplant and a waterplant, but of an electric generating and distribution system and a water gathering and distribution system. To date we are not aware of studies which have utilized such an approach.

More attention should be given to the use of dual-purpose plants for low-load-factor operation to meet peakload requirements for both electric and water systems. There appear to be many possible applications utilizing this mode of operation, or perhaps a mix of baseload and peaking plants just as with electric systems.

It further appears that the operating characteristics of electric and water systems are surprisingly similar; this, despite the fact that a water system can store water in reservoirs while storage of electricity at present can be accomplished only by pump-storage hydro installations. Nevertheless, it would appear that the concept of dispatching energy from electric generating resources on an equal incremental cost basis would be equally applicable to the dispatching of water supply resources. For example, despite the fact that millions of dollars may have been invested in the capital cost of a power generating unit, once this capital has been invested the unit will be dispatched to provide energy to the electric system only if its output is equal to or less in incremental cost than other power sources. We can see no reason why the same concept is not also valid when determining from which resource water will be taken to supply a water system. For instance, it does not seem reasonable that a water system would call for water production from a sea water conversion plant at a cost of 40 cents per 1,000 gallons (or 20 cents or even 8 cents per 1,000 gallons when there is water available to it through an aqueduct system at 7 cents per 1,000 gallons. Nevertheless, this does not mean that the waterplant does not have value as a standby and peaking resource. It is possible that it would be entirely economical to own and operate a waterplant under such circumstances to meet peakload water demands of relatively short duration in order to forestall the construction of additional aqueducts or reservoirs.

In line with the idea that dual-purpose plants might serve to supply peak water system loads, more consideration should be given to the use of existing powerplants as a heat source for the waterplant. It seems likely that under such conditions little, if any, capital cost of the electric plant need be charged against the waterplant.

The company believes that future studies of dual-purpose water conversion plants can be pursued with a much more imaginative approach than in the past. In any event, the company stands ready to assist as best it can the agencies supplying water to its service area.

Senator ANDERSON. We also have some other statements for inclusion at this point.

(The statements referred to follow :)

STATEMENT OF WILLIAM E. WELSH, EXECUTIVE DIRECTOR, NATIONAL RECLAMATION ASSOCIATION

My name is William E. Welsh. I am executive director of the National Reclamation Association.

The future growth and prosperity of our Nation, as well as the health and well-being of our citizens, will depend upon an adequate supply of good quality usable water available at all times.

The seriousness of our encroaching national water crisis is recognized by all who have studied the problem in all of its aspects. This is a problem of serious and far-reaching implications to all Americans. The rapidly increasing demands on our available water supplies will soon require every American, whether he resides in an urban or suburban, industrial or rural area, to make water his own personal concern.

Donald A. Williams, Administrator, Soil Conservation Service, and one of the Nation's foremost authorities on land and water, at the National Water Research Symposium sponsored jointly by our association and the National Association of Soil Conservation Districts, delivered a very significant address from which the following is quoted :

"Water, lifeblood of agriculture, of industry, of commerce, of life itself, cuts across every segment of our society, our economy, our daily lives * * *. The water business is serious business. It calls for our very best thinking, our best planning, action with a capital A and perhaps above all, the ultimate in coordination.

"The water supply problem is not one problem, but many. The solution is not one, but many. The people who must act are not few, but many. The people affected are not many, but everybody."

Water shortage in the arid and semiarid West has been a serious problem since the days when the covered wagon first carried immigrants to that area. For many years we thought of water shortage as being a problem only of the West—but during the past decade, it has become increasingly apparent that a national water supply which is adequate for the whole range of its uses will be a requirement and goal for all of America.

By the year 2000, our population will double and within another 35 to 40 years, it will double again, but the problems involved in maintaining an adequate supply of water for everyone is compounded by the fact that our demand for water per capita is constantly increasing.

The late Senator Robert S. Kerr of Oklahoma, who served as chairman of the Senate Select Committee on National Water Resources, in an address delivered before the same National Water Research Symposium in Washington, D.C., said :

" * * * Water is the economic bloodstream of our Nation's economy. As never before today's civilization requires more and more water to move its heavy cargoes, to cool its industrial plants, and for disposal of its wastes * * *. Our national supply situation is dynamic. The magic key to open tomorrow's doors is to solve its problems today. Action to avoid water difficulties, rather than efforts to correct them after they have occurred, must be taken if economic decline is to be avoided in many areas. Now is the time for a greater effort to find solutions to the problems that are already on the horizon."

One area of the Nation in which the water situation is already acute—in fact it has been acute for some time—is the Pacific Southwest. Adding to the seriousness of the situation in that area is the fact that the population is increasing at a tremendous rate. Citizens of the United States are not only moving westward, but they are really migrating to the Pacific Southwest at an almost unbelievable rate. The leaders of that area, who are now uniting in an effort to find the solution and the answer to the critical water problem confronting them, are already looking forward to the possibility of importation of water—perhaps from a distance as far as 1,000 miles away.

The board of directors of the National Reclamation Association, in a letter addressed to the Members of the Congress from each of the 17 Western States a year ago, said:

"The western water crisis, plus the great western migration of our population, means that we must act today if we are to meet the problems of tomorrow."

The Senate Select Committee, of which Senator Kerr was chairman, in its widely heralded report, pointed out that:

"* * * the Nation's water resources are not uniformly distributed in all the geographic regions. There are already substantial areas of water shortage in many of the river basins in the western half of the United States. On the basis of the water supply-demand studies prepared under the foregoing assumptions, full development of all of the available water resources in 5 of the 22 water resource regions into which the contiguous part of the United States was divided for the purposes of the studies will be required by 1980 or earlier, if the projected increases in population and economic activity are to be achieved. These five regions are:

"1. South Pacific.¹

"2. Colorado River.

"3. Great Basin.

"4. Upper Rio Grande-Pecos River.

"5. Upper Missouri River.

"By the year 2000 the following regions will be added to the list of those in which full development of available water resources will be required if the projected demands are to be met:

"6. Upper Arkansas-Red Rivers.

"7. Western Great Lakes.²

"8. Western Gulf."

It behooves us as a nation, in view of the critical situation confronting us, to employ and resort to all practical and legitimate means to augment our National water supply. We must strive to reduce losses through evaporation and transpiration. We must study means of controlling or eliminating water loving plants (phreatophytes); we must study the problem of evaporation losses on large reservoirs, the loss of water through seepage and deep percolation. We must find better and more economical means of transporting water to areas where it is needed.

Already great strides have been made in our efforts to find an economical means of desalination of salt or brackish water although a breakthrough does not appear to be on the immediate horizon. But the progress that has been made surely justifies continuation of the program.

The Committees on Interior and Insular Affairs of both the Senate and the House are to be congratulated upon their vision and foresight in inaugurating this program. The progress that has been made to date is, to a very large extent, due to the farsighted judgment and action of the committees in initiating the desalination program in 1952.

We especially wish to compliment Senator Anderson and Congressman Aspinall for their initiative in sponsoring the act (Public Law 87-295) passed by the 87th Congress, which greatly accelerated the saline water conversion program. We also wish to congratulate these same two gentlemen as well as those who joined with them in sponsoring legislation now before this Congress which would authorize a substantial increase in the appropriations for the saline water conversion program.

The late President John F. Kennedy, in his well-remembered natural resource message of 1962, said:

"The leadtime is long in the development of water resources * * *. Time should not be lost * * *. In the work of conservation, time should be made our friend, not our adversary. Actions deferred are frequently opportunities lost, and, in terms of financial outlay, dollars invested today will yield great benefits in the years to come."

On behalf of the board of directors and the entire membership of the National Reclamation Association, I wish to express my appreciation for the support which has been given to this program by the members of this committee.

Thank you very much indeed.

¹ It might be said that this region has already run out of water. Present deficiencies are being met by importation of water from other regions and plans are being made for additional importation from the central Pacific region.

² This is a special case, assuming availability only of runoff from U.S. portion of watershed and not considering additional use of Great Lakes water for waste dilution.

STATEMENT OF AMERICAN PUBLIC POWER ASSOCIATION

The American Public Power Association enthusiastically endorses S. 24, a bill to expand and accelerate the saline water conversion program.

Our association represents more than 1,200 local publicly owned electric utilities in 45 States and Puerto Rico. A large majority of these utilities are municipally owned, operated in close cooperation with municipal water utilities. Thus, the possibility of combining water and power production facilities is of great interest to our membership.

There are about 2,000 local publicly owned electric utilities in 48 States, supplying electricity to an estimated 30 million persons representing 13 percent of all electric consumers. Approximately 70 percent of U.S. water utilities are publicly owned and provide water to about 90 percent of the population in the more than 18,000 communities receiving such service.

Two APPA member systems already have moved ahead with programs for combination power and water desalting facilities.

In Puerto Rico, the Puerto Rico Water Resources Authority has put into operation a small water desalting plant at the Palo Seco steam generating plant, intended as an experimental facility to test the economics of building a much larger desalting plant at the south coast generating plant.

The Palo Seco plant, which produces 10 gallons of fresh water per minute, is unique in that the sea water to be evaporated is the same water that the powerplant uses to cool and condense the steam that drives the turbines. The experimental plant will use the heat that the sea water absorbs in passing through the condensers to evaporate that same water and distill it.

The possibilities of such a dual-purpose plant for municipal electric and water systems are exciting, even in areas where water is not presently in short supply.

A much larger dual-purpose plant is planned at Key West, Fla., by the Key West Utility Board, again in combination with an existing steam generating plant. Existing equipment of the municipal electric utility will be used in the first stage of the development. The utility proposes to modify a 6,250-kilowatt electric generating unit to produce heat to evaporate sea water, using a facility capable of producing 2,400,000 gallons of water per day. A second 2,400,000-gallon-per-day plant would be added in 1969 or 1970, according to present plans, in conjunction with a new powerplant to be built by the municipal electric system.

The cost of the first Key West water conversion plant is estimated at \$4,051,858 for the waterplant and \$492,000 in powerplant costs. Fresh water produced at the plant would supplement supplies of the Florida Aqueduct Commission at a cost only slightly higher than its present cost of 82 cents per 1,000 gallons. The new plant's average cost would be about 92 cents per 1,000 gallons, depending upon operating schedules.

While both of these plants involve unusual situations—the first, an island with limited water supply, and the second, one of a chain of islands obtaining their water supply via costly aqueducts from the mainland of Florida—the potential benefits from combination power and water desalting plans promise to be great in other areas as well.

Power production can play a very significant role in bringing down the cost of desalting water, similar but not identical to the part which power has played in the reclamation program. By appropriate sharing of costs, substantial economic gains are possible. They should be fully exploited.

APPA believes that the Federal Government should provide leadership in developing and perfecting techniques which will permit communities in need of supplemental water supplies to take advantage of economies which may be possible with combination power-desalting projects. Both fossil fuel and nuclear heat sources should be explored, and attention should be given to arrangements involving use of existing conventional generating equipment. While savings of scale may be significant, the program should also seek to develop dual-purpose plants of moderate size, which may be more applicable to community water problems.

Members of our association support a substantial increase in investment in the technology of water desalting, as recommended by the President and as provided for in S. 24. Such an investment will hasten the day when brackish water or water from the sea can supply a portion of our needs. It will be an investment which will pay large dividends in terms of future well-being of the American people.

Rapidly increasing need for water already has created serious problems in the Southwest and in other areas, and similar problems face the American people in all regions in the future, as evidenced by the landmark studies conducted during the 87th Congress by the Senate Select Committee on National Water Resources.

As the later Senator Robert S. Kerr declared in transmitting the committee's report:

"The nature, the immediacy, and the gravity of the water resources problems faced by the United States vary greatly from region to region, but it is clear that all parts of the country either have or will have problems. In some areas they could become quite painful, and have a far-reaching effect on the economy of the area."

The Federal program of research and development has brought the desalting of water closer to economic feasibility. It is clear that an increase in the size of this program, of the magnitude proposed in S. 24, can well bring the breakthrough that will make desalting an important source of water supply in many areas within a relatively short period.

Maximum effort at this point in time will bring maximum benefits to the entire Nation.

STATEMENT OF THOMAS K. SHERWOOD, PROFESSOR OF CHEMICAL ENGINEERING,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Let me first identify myself. I am professor of chemical engineering at the Massachusetts Institute of Technology, and an engineering consultant to petroleum and chemical companies. For some years I was dean of engineering at MIT. I have followed the activities of the OSW since its formation in 1952, and currently supervise fundamental studies of the freezing process at MIT under a nonprofit grant from the OSW. I was chairman of the committee of the National Academy of Sciences which planned and organized the 1960 Woods Hole study of research needs for desalination. I have testified before congressional hearings on this subject on several previous occasions. I am concerned primarily with the needs for fundamental research.

I am involved in this subject because I am convinced that the water problem is very real and very serious, and not because I support research for the sake of research. The most significant water statistic is the rate of "consumptive" use of water. This refers to water withdrawn from streams, lakes, and aquifers, used once, and then lost by evaporation or in other ways so as not to be available for reuse. The consumptive use of water within the continental United States is not known accurately, but is evidently between 10 and 20 percent of the total fresh water which might sometime be obtained from natural sources by present technology. Not only are the demands increasing steadily, but water supplies vary enormously with time and place, so to me this is a frightening figure.

I am further convinced that desalination is one of the several practical approaches to the problem. Two-thirds of the population lives in the 25 States which border on the oceans, and many of the other 25 States have large supplies of brackish water.

Three desalination processes are now commercial in the sense that companies are prepared to build and guarantee plants. These involve distillation, electrodialysis, and freezing. Small plants having capacities of 1 million gallons per day produce water for \$1 to \$1.50 per 1,000 gallons. Larger plants designed to produce 50 to 100 million gallons per day—enough for the municipal water needs of perhaps 300,000 people—can evidently be built to produce water for 25 to 50 cents per 1,000 gallons. Still larger plants employing nuclear reactors could perhaps produce still cheaper water if the electric power produced simultaneously could be sold at an attractive figure. These costs are high, though they are very much less than desalination costs at the time the OSW started in business.

The desalination program would appear to have two objectives—first, to do better with the processes we have; and second, to discover and develop a new and much better process. The first will be accomplished by engineering—by simpler design concepts, inventions of process modifications, the use of cheaper materials of construction, and the development of more efficient system components. To accomplish these things the engineers will draw on the fruits of the basic research program devoted to materials, corrosion, scale, properties of brines, and on the supply of data basic to the design of the heat and mass transfer equipment which is involved.

It is most important to do better with the processes we now have, if only for the reason that we may never find better ones. Even modest cost reductions would justify the expenditure of a great deal of money for research and development. A cost reduction of only 10 cents per 1,000 gallons would mean a saving of \$73 million in the 20-year lifetime of a single 100-million-gallon-per-day plant.

The second part of the desalination program encompasses the basic research which could lead to a really cheap process. Scientists, engineers, and inventors must be intrigued, stimulated, and supported. New ideas must be tested and promising leads pursued. It is a matter of faith that something enormously important will come of this, but research on similar problems in the petrochemical and chemical industries has shown an excellent payoff record. Research of this kind is a form of gambling, but the odds are excellent.

The OSW receives three to four times as many basic research proposals as it is able to support. Among these could be what we are looking for. The budget of \$4 to \$5 million per year for research is some 40 percent of the total OSW budget for each of the last 3 years. It ought to be larger. But the real trouble is that from time to time it has been deemed necessary to divert research funds to meet the urgent needs of more-or-less crash programs in the area of engineering and development. One of the principal recommendations of the 1960 Woods Hole study by the National Academy of Sciences was that the research budget be protected against just such raids.

In the light of these observations and convictions, I appeal to Congress to support the basic research program of the OSW, and to suggest ways to protect it against the financial drain of other short-term though doubtless important needs for funds. The current research program of the OSW is excellent—a nice balance of research on fundamentals and the exploration of novel ideas as to new desalination methods. It is providing technical data needed in the design of plants employing the known processes. It is actively pursuing the very promising new process called reverse osmosis. It is a program of the type and quality which justifies continuing support.

I suspect that some Congressmen have felt that basic research was a waste—that the thing to do was to select the desalination process of greatest promise at the moment, and to spend money on its development. This approach will not get us the answer which is really needed. By analogy, we might have concluded 25 years ago that the best approach to the attainment of cheap power was the sophisticated engineering development of steam powerplants. Basic research in nuclear physics could then have been abandoned and we would not now have cheap nuclear energy. Fifteen years ago the Bell Telephone Laboratories might have diverted its funds from basic research to the development of better vacuum tubes—we would then not have transistors today.

In summary, the desalination program has two objectives. The first is to improve the processes we know. The second is to learn enough about water and about separation techniques to devise a new and better process. Both are important. But the second, which depends on basic research, must have what someone has called patient money—a continuing stable budget on which to build a first-class research program.

AMERICAN FEDERATION OF LABOR AND CONGRESS OF
INDUSTRIAL ORGANIZATIONS,
Washington, D.C., April 26, 1965.

HON. HENRY M. JACKSON,
Chairman, Senate Committee on Interior and Insular Affairs,
Senate Office Building, Room 137,
Washington, D.C.

DEAR SENATOR JACKSON: The American Federation of Labor and Congress of Industrial Organizations wishes to convey its strong support of S. 24, a bill to expand and extend the Federal saline water conversion program by amending the Anderson-Aspinall Act of 1961.

This legislation would provide for an increase of \$200 million over the present \$75 million authorization ceiling, and extend the duration of the program for 5 years to fiscal 1972.

By means of this legislation \$50 million would be authorized for the program each year beginning with fiscal 1967, as compared to \$29 million requested by the President's budget for fiscal 1966.

The 1963 policy resolution on conservation of natural resources passed by the AFL-CIO convention has this to say:

"We call special attention to the Nation's water supply situation which is not only limited by natural conditions which require further storage and control as an answer, but is facing serious curtailment at the hands of man through pollution of rivers, lakes, and streams throughout the Nation and by impending regional shortages. Progress is being made through amendments to Federal water pollution control legislation. Further efforts will be required, particularly in strengthened Federal enforcement authority, expanded research, State and local action, Federal desalination programs, and national standards to determine presence of water pollution."

The AFL-CIO policy resolution also calls for the use of nuclear energy for saline water conversion.

In his saline water message of March 29, 1965, to the U.S. Senate, President Johnson wrote:

"By pressing ahead with a vigorous program of economic desalting to meet our ever-growing domestic needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could provide the key that will unlock the door to economic growth for many of these nations."

Organized labor shares the President's hopes for the early fruition of this Nation's 12-year-old water desalination program.

In 1961, in supporting the legislation which was to be enacted into law as the present desalting program, we urged that converted saline water be made competitive with other sources in cost before 1980. If such a goal is not achieved, we stated, "local and regional water shortages which already spot various sections of the Nation will seriously affect the national welfare."

Since that time, although progress in saline water conversion technology has been made, much still needs to be done. The Federal program must have all necessary resources made available to it to carry out successfully "the substantial sustained effort necessary to achieve truly economical desalting of sea and brackish waters," in the words of the President's saline water message.

We feel that it is questionable, however, that the increased authorizations asked for in this legislation are adequate to accelerate the Federal water desalting program to a point where decisive breakthroughs in the technology of conversion will take place within the next decade.

It is the strong opinion of the AFL-CIO that the saline water conversion program must be expanded far beyond the increased authorizations provided by S. 24. We urge that this committee request the Secretary of the Interior to submit a report and recommendations for further acceleration of the program to the Congress for its review and action not later than January 31, 1966.

We also respectfully request that this statement be included in the record of your committee's hearings on this bill.

Sincerely yours,

ANDREW J. BIEMILLER,
Director, Department of Legislation.

CHAMBER OF COMMERCE OF THE UNITED STATES,
Washington, D.C., May 26, 1965.

Senator HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate,
Washington, D.C.

DEAR SENATOR JACKSON: In connection with your consideration of S. 24, the Chamber of Commerce of the United States supports Federal saline water conversion research, provided that it is limited to fundamental scientific research, technological exploration, and conceptual design.

We have two major areas of concern about the saline water research program: (1) The manner and extent to which the program is implemented and (2) the amount of funds to be authorized.

It is our position that the program should:

1. Be conducted by private enterprise insofar as possible. Government should only supplement private effort or perform such research as the private sector is unable or unwilling to perform.

2. Not include construction and operation of large-scale pilot plants capable of commercial production of potable water. This activity should be conducted by private industry or by the level of government covering the area to be served by the facility—i.e., a town or city, a county or State, or perhaps a grouping of local and/or State governments in a regional compact.

3. Be compared on an economic basis with all other water research programs. This is essential to provide the most economical supply of water.

4. Ascertain the demand for desalinization in different areas of the Nation. A variety of water supply systems is indicated due to varying needs and supply sources.

We do not have adequate information upon which to base an informed recommendation as to the appropriation authorization. In transmitting to the appropriate congressional committees our recommendations with respect to the fiscal year 1966 budget request of the Interior Department's Office of Saline Water, we emphasized that—

"* * * Any opposition to the enlargement of the saline water program stems from a concern about the feasibility of enlargement. It should be based on need and careful consideration must be given to the relation of cost to worth."

We would appreciate your giving careful consideration to these views and having them made part of the official record of your hearings on this legislation.

Sincerely,

THERON J. RICE,
Legislative General Manager.

BLAW-KNOX Co.,
Pittsburgh, Pa., May 20, 1965.

HON. CLINTON P. ANDERSON,
Chairman, Subcommittee on Irrigation and Reclamation, Committee on Interior and Insular Affairs, U.S. Senate, Washington, D.C.

MY DEAR SENATOR ANDERSON: With the holding currently of House and Senate hearings on the President's goal to economically produce potable water from saline water, I should like our company's views to be known as favoring continuation of the saline water program.

Blaw-Knox Co. has been actively engaged since 1959 in the development of a freezing process for desalination of salt water. We know that through our 3-year operation of a pilot plant in St. Petersburg, Fla., and the support of the Office of Saline Water, that genuine progress has been made toward development of essential information on the freezing process. Conservative estimates of water costs based on pilot plant operations indicate that in commercial plants of selected capacities it will be possible to produce potable water from sea water more cheaply by the freezing process on which we have worked than by others. Additional pilot plant development work will, however, be required before the final design and sizes of component equipment for commercial size plants can be determined.

It should be borne in mind that desalination of water by freezing processes is of comparatively recent origin. Yet, the progress that was made in the brief time the Blaw-Knox effort was maintained can be regarded as most encouraging.

We see the development of economic methods for the utilization of sea water to supplement sources of natural water for general consumption as a highly important objective for this Nation. We believe the Congress should acknowledge the necessity of further and immediate development work to advance the remaining know-how required to permit the earliest possible move to commercial plant status in the desalination of water. In line with this view, we recommend strongly that the program for development work in saline water be continued and that the objective be supported in the current congressional hearings.

Further, we should like you to know of our willingness to appear before any congressional committee hearings on this subject, and will await your request to us for such participation.

Sincerely yours,

W. CORDES SNYDER, JR.,
Chairman of the Board.

Senator ANDERSON. This concludes the hearings.

(Whereupon, at 1:10 p.m. the hearing in the above-entitled matter was concluded.)

SALINE WATER CONVERSION PROGRAM

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HEARINGS
BEFORE THE
SUBCOMMITTEE ON
IRRIGATION AND RECLAMATION
OF THE
COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
HOUSE OF REPRESENTATIVES
EIGHTY-NINTH CONGRESS
FIRST SESSION
ON
H.R. 7092
TO EXPAND, EXTEND, AND ACCELERATE THE SALINE WATER
CONVERSION PROGRAM, CONDUCTED BY THE
SECRETARY OF THE INTERIOR

MAY 20 AND 21, 1965

Serial No. 7

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Committee on Interior and Insular Affairs



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TO EXPAND, EXTEND, AND ACCELERATE THE SALINE WATER CONVERSION PROGRAM, CONDUCTED BY THE SECRETARY OF THE INTERIOR

THURSDAY, MAY 20, 1965

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION,
OF THE COMMITTEE ON INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:50 a.m., in room 1324, Longworth House Office Building, Hon. Walter Rogers (chairman of the subcommittee) presiding.

Mr. ROGERS of Texas. The Subcommittee on Irrigation and Reclamation will come to order.

We have before us for consideration the pending bill, H.R. 7092, by our distinguished chairman of this committee, the Honorable Wayne Aspinall of Colorado, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

This legislation was recommended by President Johnson in executive communication No. 828, printed as House Document 128, a copy of which is attached to the bill before each member. And without objection, a copy of the bill will be printed in the record at this point together with the communication from the President of the United States.

I presume, Mr. McFarland, we have not yet received the Department report.

Mr. McFARLAND. Yes, the communication from the President, printed as House Document 128, constitutes the administration's recommendations.

(H.R. 7092, with H. Doc. 128 follow:)

[H.R. 7092, 89th Cong., 1st sess.]

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words “, module, component,” after the word “laboratory”.

(2) In section 8 substitute the figure “\$275,000,000” for the figure “\$75,000,000” and the figure “1972” for the figure “1967”.

[H. Doc. 128, 89th Cong., 1st sess.]

COMMUNICATION FROM THE PRESIDENT OF THE UNITED STATES TRANSMITTING A DRAFT OF PROPOSED LEGISLATION ENTITLED, "A BILL TO EXPAND, EXTEND, AND ACCELERATE THE SALINE WATER CONVERSION PROGRAM CONDUCTED BY THE SECRETARY OF THE INTERIOR, AND FOR OTHER PURPOSES"

THE WHITE HOUSE,
Washington, March 29, 1965.

Hon. JOHN W. McCORMACK,
Speaker of the House of Representatives,
Washington, D.C.

DEAR MR. SPEAKER: Past generations of Americans have been blessed with an abundance of sparkling, clean water. But in recent years we have become careless in our stewardship of this vital resource—polluting, wasting, and carelessly exploiting it.

Water shortages—real as well as prospective—already plague some regions of our land. Other areas and communities will soon be threatened. Yet, we must have an abundance of fresh water if we are to continue to grow and prosper.

Action to conserve what nature has so generously provided has often been inadequate and too late. We are determined not to make this mistake again. I have already pledged full support for cleaning up our rivers—and keeping them clean. We will continue to foster conservation by planning for the wisest possible use of all existing water supplies and by curbing and eliminating wasteful and uneconomic uses of water.

But these steps are not enough. New sources of supply at competitive costs are also required if we are to stay abreast of the ever-mounting demand for water. The seas around us offer an inexhaustible reservoir to help meet this need in coastal areas while vast quantities of brackish water are available to supplement the supplies of many inland areas. We must spare no effort in learning how to desalt these waters economically.

For the past 12 years the United States has been engaged in a program of research and development which has brought desalting technology to a point where it shows promise of economic application in the future. To stimulate the translation of this promise into reality, I requested the Department of the Interior last July to develop, in close collaboration with the Atomic Energy Commission, a proposed program which would significantly advance large-scale desalting technology.

The resulting report entitled "Program for Advancing Desalting Technology" was completed promptly and released to the public on October 26, 1964. It recommended—and I am transmitting with this letter draft legislation to accomplish—expansion, extension, and acceleration of the salt-water conversion research and development activities now being conducted by the Department of the Interior under authority of the Anderson-Aspinall Act of 1961.

This legislative proposal would increase by \$200 million the \$75 million appropriation authorization provided in the 1961 act and extend through 1972 the time during which the authorized funds would be available to support this important program. Enactment of this legislation is vital if the Department of the Interior is to mount and lead the substantial sustained effort necessary to achieve truly economical desalting of sea and brackish waters.

In the meantime, I have already transmitted to the Congress a request for a supplemental appropriation of \$3.9 million in 1965 to enable the Department, through a reorganized Office of Saline Water, to accelerate its research and development activities along the general lines outlined in the report mentioned above. Desalting activities will receive continuing emphasis in 1966. My budgetary recommendations to Congress for the coming fiscal year amount to \$29 million for the Office of Saline Water, more than double the amount appropriated for 1965.

By pressing ahead with a vigorous program of economic desalting to meet our ever-growing domestic needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage. To stimulate cooperation in the field with such great potential

for the good of mankind, the United States will convoke a symposium of interested nations in October 1965 to exchange information on desalting technology.

In recommending this measure to the Congress, I wish to acknowledge the foresight of such able legislators as Clinton Anderson, Wayne Aspinall, and the late Clair Engle. Our present efforts in desalting rest in substantial measure upon the sound foundation they laid and on which we intend to build. I earnestly hope that their leadership and the progress which it has inspired can be carried forward without interruption by the prompt enactment of the bill I am transmitting today.

Sincerely,

LYNDON B. JOHNSON.

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words " , module, component," after the word "laboratory".

(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,900,000" and the figure "1972" for the figure "1967".

Mr. ROGERS of Texas. The bill before the committee today would expand, extend and accelerate the saline water research program conducted by the Secretary of the Interior. An additional \$200 million would be authorized for conducting this program and the life extended 5 years.

The Federal saline water research program was initiated in 1952 with the authorization of \$2 million and a 5-year program.

In 1955 the program was extended to 10 years and the amount authorized was increased from \$2 million to \$10 million.

In 1958 Congress authorized the construction of not less than five demonstration plants with a ceiling of \$10 million for the demonstration plants program.

In 1961, the research and development program was extended 5 years through fiscal year 1967 with an authorization of \$75 million for the 6-year period, fiscal 1962 through fiscal 1967.

In summary, \$82,500,000 has been authorized for research and development and \$10 million has been authorized for construction of demonstration plants.

As I stated a minute ago, H.R. 7092 would authorize an additional \$200 million.

We have a number of witnesses who desire to appear in reference to this matter. We are honored this morning to have as our first witness the Honorable Stewart D. Udall, Secretary of the Interior, but before recognizing the Secretary, I want to recognize the chairman of the full committee, the Honorable Wayne Aspinall of Colorado.

Mr. ASPINALL. Thank you, Mr. Chairman. I am most appreciative that you saw fit to give the résumé of the history of this legislation that you did.

The chairman of the committee and other members of the committee have been criticized from time to time and labeled as being unfriendly to the saline water program. I think that all you have to do is to look at the history as to how this has developed in order to learn the

fine friendship of the House Committee on Interior and Insular Affairs for the program—and that means every member of the committee.

It seems as if there is always a desire on the part of some people who are interested in the administrative operation to be critical of the methods of Congress when the Congress wishes to look into the administration of a program. This happens to be a program that is the responsibility of this committee. It is a program that catches the eye of the public and holds the attention of the people of the United States and, I might say, of the world. Because of that, it is supposed to have a great deal of political muscle behind it—whatever that means. It is supposed to be a program that will appeal to the public. This is the reason why we have had the great leaders of our country saying at times that this kind of a program could make the deserts bloom, when most of us who knew anything about irrigation know that the irrigation waters sell for \$1.50 to \$6 an acre-foot as a rule, with an upper limit of approximately \$25 an acre-foot for very specialized products.

So far, the water that has been proposed to be obtained from sea water will be at a cost of \$1 to \$3 a thousand gallons, which means anywhere from \$335 to \$1,000 an acre-foot.

Also, the program has been publicized as a possible program to help our international allies. Well, a funny thing about it is that those of us who have worked with this find that some of the other countries have engaged in these undertakings and activities for a long, long time, and in many respects they are ahead of us.

What this committee has to do, as we study this legislation, is to see to it that there is a reevaluation of the activities carried on heretofore during the life of the operation and that there is a good case made for any future operations, not in order to keep scientists busy, not in order to keep administrators busy, not in order to keep the Congress before the public in a good light as far as publicity is concerned, but in order to see to it that the taxpayers' dollars are properly used. That is all that we are interested in, that a case be made for the \$200 million within the foreseeable future and, if so, this committee is undoubtedly going to be favorable to this proposition. I would suggest that the case will have to be made, because some rather critical statements have been made about the program to date and what is proposed in the future.

I may say, Mr. Chairman, that I make this statement because we are for the program, but this is not a program on which we can waste the taxpayers' dollars simply because it happens to be a program which catches their eye.

Mr. HALEY. Will you yield?

Mr. ASPINALL. Yes.

Mr. HALEY. I want to just say "Amen" to what the chairman of the full committee has just said. I think that in this committee, as a whole, that this program has unanimous support. I think that this is a fine program. Ordinarily, I do not support these things.

I think that one thing that has probably disturbed the members of the committee a considerable amount, is the fact that at this moment this is a limited field in which the manpower is not available. I think the testimony will show that.

I think that this committee has always been sympathetic, and I will say unanimous, in support of this program. We have found that there has been a rise in costs more than was anticipated when the program was initiated several years ago. However, it has had the support of this committee. I hope that it will continue to have the support of this committee.

But I, like the chairman, sometimes wonder why the Congress and this committee has been criticized because some people think that it is not moving forward fast enough.

I have always taken the position that dollars alone do not accelerate a program. The people capable of doing this work, I think, are very necessary. And just to pour out taxpayers' dollars on a crash program, I do not think will accomplish the purpose. I think that we want orderly progress. And I think that you should have orderly progress in this program.

A word of caution about it. Do not push along too fast and do not ask for more dollars than you can justify expending in an orderly manner.

Mr. HOSMER. Will you yield?

Mr. ASPINALL. Yes.

Mr. HOSMER. I would like to add that Mr. Holum of the Department of the Interior testified that from 1952, apparently, through fiscal 1965, there was a cost of \$42 million, 12 million for construction and around \$30 million for research and development, notwithstanding the fact that there has been authorized, as the chairman of the subcommittee has stated, a total of \$82.5 million and \$10 million more has been authorized for construction of demonstration plants. If this \$200 million is added, that means an expenditure at the rate of at least \$40 million a year over the next 6 years, immediately twice the rate of the rate of the total program at which the earlier experiments have been carried on. That does not make too much sense to me.

In addition to that I have some qualms about what this committee's function is. Most witnesses have stated heretofore that this was in the realm of agriculture. Another witness stated that it is not. If so, probably it is outside of the jurisdiction of the Irrigation and Reclamation Committee. As a consequence, some have a feeling that what is being asked for here, in addition to the other appropriations is not a realistic figure, that is, the \$200 million. We seem to have taken up what seems to be somewhat similar to a pursuit of the Holy Grail. I wonder how realistic we are being in that relation.

Mr. ASPINALL. May I say in reply to the statement of my colleague, in one of the last phrases that he used, that I do not agree, but I think I understand his feeling. We did authorize a term of years for the program that now exists. We authorized the money for that period. The executive department and the Bureau of the Budget asked for all of the money for fiscal 1966 without considering that there was another year in the authorized period. It was not forthcoming in the appropriations bill and that is proper in my opinion.

That is all I have to say.

Mr. ROGERS of Texas. I think that I can say that this is a controversial program—we are all conscious of that and we are having difficulty with it.

Our next main thought is that it is much easier to spend money than it is to treat salt water. We hope that this can be brought into balance. That is one of the purposes of these hearings, to get the matters before the members of the committee and before the Congress, to find out just which road is the proper one to take to get the results that we started out seeking a long time ago.

We are pleased to have with us this morning the Honorable Stewart L. Udall, Secretary of the Interior, who will be the first witness and will be accompanied by Mr. Frank C. Di Luzio, the Director of the Office of Saline Water.

We are glad to welcome you back before the committee, Secretary Udall.

**STATEMENT OF HON. STEWART L. UDALL, SECRETARY OF THE
INTERIOR; ACCOMPANIED BY FRANK C. DI LUZIO, DIRECTOR,
OFFICE OF SALINE WATER**

Secretary UDALL. Mr. Chairman and members of the subcommittee, thank you very much. It is always a pleasure to meet with my former colleagues.

I would like to try to put this whole subject that Chairman Aspinall mentioned a moment ago into sharp focus. I have a prepared statement, Mr. Chairman. I will read most of it, but I would like to summarize parts of it, too, if I may have that privilege.

Mr. ROGERS of Texas. Did you want to submit your statement for the record and to summarize it?

Secretary UDALL. That is right. I will read parts of it, but I would like it to appear in the record in full.

Mr. ROGERS of Texas. Without objection, your statement will be included in the record the same as if it had been read in full and you may summarize it.

Mr. HOSMER. You have testified a few days ago in the Senate. Is this the same statement as you presented before the Senate Committee?

Secretary UDALL. The tenor is about the same—although it is different in some respects.

I still have enough of a Congressman in me to realize, and be ready to admit, that there are many important programs in terms of national interest that have begun through congressional initiative and leadership rather than leadership downtown, and I think that this program is one of those. I was not in Congress when it began, but I think that some of the gentlemen in the room today, former Senator Clair Engle, and the President himself as a Senator, as well other Senators were the earlier supporters of this program. This, really, from the beginning, has been a congressional program, one that the congressional committees have taken a particular fatherly interest in, and have followed it very closely. And quite to the contrary, instead of criticizing this committee I would be one who would point out that special recognition is deserved. This is an instance where Congress felt that action was necessary and pioneered a program. We come back from time to time to have the program reviewed. It is reviewed annually by the Appropriations Committee. I think that this type of close scrutiny and interest has helped the program over the years. I want to make that point here this morning.

Mr. ROGERS of Texas. The Secretary, of course, is cognizant that this is not criticism of this program.

Secretary UDALL. This committee had an early review of the program, I believe, in February and I think that it is important that we get right to the matter that the committee is primarily interested in and not repeat all of the subjects that we went into then. I am sure that the committee will be very much interested in what some of the industry witnesses have to say. We have all realized from the beginning that this is basically a research effort, that the Federal Government is not going to end up building plants and hardware. When you get into the final phases industry will take the program and run with it. This is what has been intended, and I think that this is one of the first times that the committee has heard industry witnesses. I think that this is a very fine development.

I would like to say, too, Mr. Chairman, although he has only been aboard for 4 months, and that Mr. Di Luzio has already established himself in my mind as one of the finest administrators and bureau chiefs I have. I think that you will find that he is very candid and has a great deal of insight into this program.

Last July the President asked the Department of the Interior, in cooperation with the Atomic Energy Commission, to develop "an aggressive and imaginative program to advance progress in large-scale desalting of sea water."

H.R. 7092 provides the basic legislative authority required if the program is to be carried to a successful conclusion in a reasonable period of time.

I am completely convinced that this is the appropriate time for a significant "leap forward" in our total national effort to achieve economic methods for making sea water usable for municipal and industrial purposes and for improving the quality of brackish water. An accelerated program is particularly timely for the following reasons:

(1) The 1961 Anderson-Aspinall Act has made it possible for the Office of Saline Water and the American research and industrial community to accumulate the basic scientific and engineering data that make the program possible.

(2) American industrial know-how is mobilized and ready for an accelerated program. An impressive list of some of the country's best firms have mobilized their finest talent. If we move aggressively at this time, we can take full advantage of the competitive instincts of the American business community to the advantage of the desalting effort and American industry.

(3) In our own country and around the world, more and more communities are finding economic growth stultified either by an absolute shortage of water or by the poor quality of the supplies that are available. A well-planned, balanced accelerated program today can eliminate the need for a wasteful crash program in the near future when water deficiencies become intolerable.

I am completely convinced that this is the appropriate time during the years ahead. The city of New York, our largest city, was faced with a very serious water problem this year.

We plan a balanced program. We recognize that there are two substantially different requirements which must be met. Major metro-

politan centers and densely populated regions close to the sea coast require large quantities of water and substantial and growing amounts of electric power. Both of these requirements can be met economically by large dual-purpose water desalting and power generating facilities using a common heat source.

Perfecting our ability to build plants of this magnitude is largely an engineering job which must be supported by basic research as critical and unsolved problems are identified. The Federal Government should share the risks on an appropriate basis with the industry and local communities as first and second generation plants are built in the various size ranges.

More basic research and careful evaluation of currently known, but unproved processes, are necessary before we can determine which process or processes will meet the needs of small communities. It may well be that a completely new idea will have to be developed before we achieve the necessary economies.

The program you are considering today plans an accelerated effort in both basic research and process development to meet this need that becomes more critical every passing year to inland communities, small islands, and communities along the coast.

As you know, the Department of the Interior and the Atomic Energy Commission are currently participating in two engineering and economic feasibility studies of large plants. One study is being made in cooperation with the Metropolitan Water District of Southern California, the largest municipal water company in the country. Bechtel Corp. is conducting this study. It is scheduled for completion in October. MWD would like to have this plant in service by 1970. The second, with the Government of Israel, is being made by Kaiser Engineers. Israel would like to have this plant "on stream," if possible, in 1971.

Both studies will add substantially to the national know-how as it relates to the construction of large dual-purpose plants. If the projects prove to be economically attractive, the studies will form the basis for appropriate decisions as to further action.

This committee will have to participate in this decision, of course.

As I have noted, the Atomic Energy Commission is a partner in each of these studies. We have and will maintain a close and cordial relationship with the Commission as their program complements the Department's responsibility in the desalting field. Economic desalting requires cheap energy. In many areas, a nuclear reactor may be the cheapest heat source; in others it may be a fossil fuel. We must keep ourselves informed of all developments in the energy field as we move ahead and we do.

In cooperation with the Department of State, we have arranged the First International Symposium on Water Desalination, which will be held in Washington, D.C., on October 3 to 9, 1965. We have extended invitations to all countries with which we have diplomatic relations. Fifty-three nations already have indicated their intention to send official delegations to the meeting. Total attendance is expected to number some 700 to 900 individuals, perhaps even more, representing the world's outstanding talent in desalting research and engineering.

During the past year, we exchanged visits of delegations on desalting with the U.S.S.R. and, in November, our countries entered into an agreement to cooperate in desalination, including the use of nuclear energy for that purpose. To date, no formal actions have been taken under this agreement, but we anticipate that the first step will be an exchange on a reciprocal basis of technical experts who will make detailed inspections of work that is of special interest to each country. The Soviet Union seems to be sponsoring a rather comprehensive desalting program. And my experts reported that they are making progress.

The team of experts who visited Russia did not have time for a full study of the Soviet effort, but they reported significant engineering accomplishments. They are operating a plant of 1.5 million gallons per day which serves as the sole source of water supply for the 20,000 people of the city of Schevelenko that is being built on the Caspian Sea. They plan to build a powered, dual-purpose plant at this same location; in fact, the reactor already is under construction. The initial visit to the Soviet Union convinced our representatives that we could benefit substantially from an exchange of technical information.

The International Atomic Energy Agency is actively promoting a desalting program as a part of its effort to stimulate the peaceful use of the atom. Interior and the Atomic Energy Commission are cooperating with the Agency in this endeavor.

Chairman Seaborg has asked Commissioner Ramey to maintain day-to-day liaison with the Department at the policy level. Assistant Secretary Holum has a like responsibility for Interior. We have a fine working relationship with him, also. Together they work closely with the Department of State to make certain that American expertise in the desalting field is available to our world neighbors. We consider it important that they know what desalting can do to assist their economic development. We consider it equally our responsibility that they know what it cannot do—so as not to expect miracles that are not attainable from presently available technology.

The legislation we are considering this morning is the basic ingredient of a successful "leap forward" if we are to develop the end product that will soon be urgently needed both at home and abroad. There is little doubt that additional congressional directives providing more authority to the Department will be required as the program develops. It may very well be that when these feasibility studies that we have out are in next fall that we may be back with additional legislation. We might need it.

Certainly we can predict that information developed by researchers and engineers will need to be tested in prototype plants. However, we consider it inappropriate to attempt to make those recommendations on the basis of the incomplete data that is currently available. We expect any recommendations that we make in the future to fit within the framework of H.R. 7092.

In summary, I am convinced that, as a Nation, we are going to solve the complicated problems associated with the desalting program. The American research and industrial community has the talent to do the job. The Federal Government should appropriately share the risks involved with American industry and the communities that

build the pioneering plants. H.R. 7092 is designed to accomplish that goal.

I think that we have made orderly, steady progress over the years. This has not been a crash program. It should not be. I think that the type of close supervision by the committees of Congress, the type of keen interest by industry are the two things that have made this an orderly program.

Mr. Chairman, Mr. Di Luzio is here with me. Of course he is going to testify on the details of the program. My statement is deliberately general, addressed to the large picture, and I appreciate this opportunity to appear before the committee.

Mr. ROGERS of Texas. Thank you, Mr. Secretary. The Chair recognizes the gentleman from Colorado, Mr. Aspinall.

Mr. ASPINALL. I do have a few questions of the Secretary. I will have questions of Mr. Di Luzio later on.

Mr. Secretary, does this "leap forward" that you referred to in your statement, and the emphasis on large plants indicate that after 13 years of study we are conceding there is little hope of the major breakthrough that will produce truly low-cost conversion?

Secretary UDALL. That is a tough question. I do not want to mislead the committee in any way, but I think that what I am trying to imply to the committee when I talk about a "leap forward" refers primarily not to some research—some sudden breakthrough or some sudden new answer, but to the fact that we have reached the point now where the research effort authorized by this committee 4 years ago is about ready to pay off. I think that you will find in the testimony from the industrial people and from Mr. Di Luzio that there is a general feeling that within the period covered by this authorization, we should be building and completing some large plants; that the experience out of that work is going to provide us with answers that we do not now have. It will bring the cost down. I think that when we get to perfecting the processes, we are not interested in a big plant program. That is another factor I want to underscore. I think in the long run, for this country, it may be that the most important thing is for small- and medium-size plants to supply small- or medium-size communities. This is an area where the research effort is particularly important.

Mr. ASPINALL. I understand that with the exception of the ion exchange program that we have, so far as processes are concerned, there has been no breakthrough and practically the only thing that we can look for, so far as a practical program is concerned, is to put our hardware together, is that right?

Secretary UDALL. I would want Mr. Di Luzio to comment on this because—

Mr. ASPINALL. I will ask him some questions later on.

Secretary UDALL. I want to state my own feeling on this, because this does concern the larger aspects of the program. I think that we have, for example, in these demonstration plants learned a great deal in terms of refining and perfecting processes. This is a very important aspect of it. I think that we have learned a great deal with regard to the value and the merits of various of the processes. There are some that were thought promising 5 years ago that do not look so promising now. I think that we have identified, in terms of our research efforts those that show the most promise and that can be perfected. The reverse osmosis process, for example, is a new one

that we were not even talking about 2 years ago. Just how well this develops through research is another answer that will emerge in the months ahead.

Mr. ASPINALL. The only process that we have ruled out—and we have had only five until recently—we talked about the reverse osmosis which is an improvement upon one of the other processes—the only one that was ruled out so far, because you have not been able to come up with some kind of an operation, is the freezing process, is that not true?

Mr. DI LUZIO. May I answer that, Mr. Chairman?

Mr. ASPINALL. If necessary.

Mr. DI LUZIO. We do have two freezing processes which are now in the pilot and demonstration plant stage of development at Wrightsville Beach. One process has been operating in a plant overseas and also has been operating in a pilot plant in Beloit, Wis.; this pilot plant is now being erected at Wrightsville Beach for further tests and development when operating on sea water.

Mr. ASPINALL. All right. Let me ask you this question, Mr. Di Luzio. Maybe I misunderstood the Secretary. He said that you were ruling out some processes. You only have the five processes, plus the reverse osmosis, wherever that fits in. Which ones have you ruled out?

Secretary UDALL. I did not intend to imply that we have ruled it out.

Five years ago the conception that I had was that the freezing process was just as promising as any other. We are doing some research and development in this field; this is a process that, after the research we have done, and the effort that has been made up to this point, does not look as promising as some of the others do at the present time.

Mr. ASPINALL. Of course I wonder sometimes if there is ever a time that the scientist rules out any process and ends operations which he had some interest in. I think this is true with all of us. So what is really involved here is a question of more emphasis, perhaps, on some processes that we had a few years ago and less emphasis on others?

Secretary UDALL. That is a good description.

Mr. ASPINALL. Do you believe that the recommended acceleration of the program in this legislation and the expenditure of \$200 million will provide the "aggressive and imaginative program to advance progress in large scale desalting of sea water" which the President called for?

Secretary UDALL. I think that the authorization that we have asked for here in terms of the expansion during the period from now until when the old program expires in 1972 is about the scope of the program. That is our best judgment.

Mr. ASPINALL. For basic research or for applied research?

Secretary UDALL. Both.

Mr. ASPINALL. Well, you just got through telling us in your statement that you more than likely or possibly would be back here next year or the year following with an additional request for additional moneys to construct and operate large demonstration plants. I understood you to so say.

Secretary UDALL. Let me be quite candid with the committee. I think it is very important that you understand this. Let us talk about the metropolitan water district proposition in southern California. This is presently under study. We do not have the answers on this. We do not know how the pieces are going to be put together. It is a three-way, and it may even develop into a four- or five-way, proposal

before we get through. It now involves the Department, the Atomic Energy Commission, and the metropolitan water district.

Let us say that this study shows, in terms of engineering and economic feasibility, that a large plant is possible. Let us suppose that we conclude and decide to recommend to the Congress that there should be a large plant.

Now, the extent to which the Federal Government should participate is very much uncertain at this time. We are certain, I think, at this point, that the plant should be built, undoubtedly built by the Metropolitan Water District. It may very well be that this will be part of a waterpower combine and that public or private power companies will be involved in this, also.

This is one of the new things that is beginning to emerge already. Whether or not the Federal Government participates in simply investing money in the project, to the extent that it is needed with regard to applied research and basic research, because the big plant—the first big plant of this kind is, essentially, or will be a research instrument, too—or whether the Federal Government makes a component of the basic investment we do not know yet, and we will not know until this study is in and we have set down around the table with these people.

So this is one of the things that I wish that I could spell out for the committee. It is one of the things that I think that the committee certainly will want to look at or want to pass judgment on itself, and this is the reason when the reports are in (which are being made by very fine engineering firms) that we sit down and analyze them. And I expect we will be back next January or February wanting to tell you all about it and to discuss with you the various alternatives under which projects of this kind might be launched.

Mr. ASPINALL. I certainly would want to hear about it. The thing that I do not want to happen is what happened to Freeport. You do not know yet, do you, Mr. Secretary, what will happen to the plant at Freeport?

Mr. DI LUZIO. Mr. Chairman, we do not, because Freeport in my estimation has served its purpose as a demonstration plant. And we have an investment there. It is a good hydraulic system and we would like to use that test bed for different concepts in fluted tubes because we think this will be a low-cost water, falling film, plant.

Mr. ASPINALL. Can you furnish water to the municipality at a low cost?

Mr. DI LUZIO. The price of the water was established on the basis of facts which I am not familiar with. The price of the water to the city of Freeport has really nothing to do with the cost of water from the plants. We had to dispose of the fresh water—it would be a crime to waste it—and they are willing to take it, at a few cents per thousand gallons; but as a test bed, the Freeport plant is very valuable as equipment for use in engineering development.

Mr. ASPINALL. I think that last statement is correct, but yet we have not been advised as to what you intend to do with it. Mr. Secretary, in your report of September 22 to the President it is indicated that you utilized the services of several outstanding scientists and consultants. I would like to know if this group submitted a report and recommendations on the program as a group or as individuals? Could the committee have whatever reports or views that were submitted by this group?

Secretary UDALL. The Director advises me that—and this is my recollection—this group of consultants did submit a report. I think this went both to us and to the science adviser, that is, the President's science adviser. I see no reason why the committee should not have a copy of it. We will be glad to provide it.

Mr. ASPINALL. We should have had it right at the beginning, should we not?

Secretary UDALL. I am surprised that you had not received it.

Mr. ASPINALL. We are, too. We are very surprised.

(The information follows:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., June 3, 1965.

HON. WALTER ROGERS,
Chairman, Irrigation and Reclamation Subcommittee, Interior and Insular Affairs Committee, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: In response to the question posed by Mr. Wayne Aspinall at the hearing on H.R. 7092, to expand, extend, and accelerate the saline water conversion program, I am pleased to provide the committee with the following information:

Enclosed, please find a copy of a letter, dated July 15, 1964, which I received from the then Director of the Bureau of the Budget, Kermit Gordon, which directed the Department of the Interior, in close collaboration with the Atomic Energy Commission and the Office of Science and Technology, to take immediate action to develop a plan for an aggressive and imaginative program to advance progress in desalting of sea water. You will note in Mr. Gordon's letter that he requested an interim report within a week in which we would advise him of the steps we were taking to develop the new program.

We are also enclosing a copy of my response to Mr. Gordon dated July 21, 1964, in which I advised him that I had directed my science adviser, the Director of the Office of Saline Water, the Assistant Chief, Division of Project Development of the Bureau of Reclamation, and the Director of the Division of Management Research to work closely with the Assistant Secretary for Water and Power to develop this program. In addition, Mr. Robert Vaughan, who had been Under Secretary Carr's principal assistant in the desalting effort, was reassigned to Mr. Holum's office to work full time on this effort.

It was considered highly desirable to have the views and assistance of competent people from outside of the Government in preparing and completing this review and reorientation of the Department's program for water desalting. Accordingly, we arranged for consulting services from Dr. T. K. Sherwood, Dr. Abel Wolman, and Prof. Rolf Eliassen. Ted Schad of the Library of Congress worked with the group as an observer.

The consultants met on several occasions with Department personnel and offered a number of worthwhile comments and suggestions concerning the program, many of which were included in the final report, but they did not list their recommendations and submit them in writing. The fact that their suggestions were offered orally does not diminish the value of their contribution to the Department.

Sincerely yours,

STEWART L. UDALL,
Secretary of the Interior.

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington, D.C., July 15, 1964.

HON. STEWART L. UDALL,
Secretary of the Interior,
Washington, D.C.

DEAR MR. SECRETARY: The President has instructed me to ask the Department of the Interior, in close collaboration with the Atomic Energy Commission and in consultation with the Office of Science and Technology, to take immediate action to develop a plan for an aggressive and imaginative program to advance progress in large-scale desalting of sea water. In developing the plan, the following factors should be considered:

1. Significant advances in desalting would yield major benefits to nations throughout the world, as well as to urban and industrial users in water-short areas of this country. Steps are already underway to provide for cooperative studies in desalting by the United States with other nations. In developing your plan, full recognition should be given to the importance attached by the President to sharing the benefits of American desalting technology with other nations.

2. The ongoing Federal saline water conversion program has concentrated on research, and a limited development effort. While substantial progress is being made, much remains to be done, particularly on measures to advance the technology of large-scale desalting plants.

3. Every means should be explored to increase momentum and advance desalting progress—by exploiting the currently most developed technology (evaporators), using both conventional or nuclear fuels or both, and by vigorously pursuing other alternatives which may prove superior in the longer run. New approaches should be developed, and creative thinking should be applied to solving problems that defy conventional engineering solution.

4. Federal scientific and technological resources should be marshaled to provide the most effective and streamlined mechanism possible for accelerating progress in desalting. Organizational arrangements should be devised and technical and scientific personnel made available to assure the reorientation of program emphasis needed to take full advantage of current technological developments. The plan should provide for full use of existing research and development facilities and capabilities within and without the Federal Government, as necessary.

5. The Revelle study recently made under the auspices of the Office of Science and Technology indicates that large-scale nuclear powerplants coupled with large-scale desalting plants could produce power and water at competitive costs by about 1975 and in many water-short coastal areas. Your plan should propose an optimum strategy and time schedule for relating the development of large-scale nuclear power technology to the development of large-scale desalting technology.

6. Special attention should be given to the need for current and reliable information on comparative water supply costs, and related economic data. Also, the responsibilities and capabilities of State and local governments and of private enterprise should be fully recognized in preparing the plan. Particular attention should be given to the development of appropriate cost-sharing principles to guide financial discussions with States, municipalities, and private companies in experimental ventures to meet this need.

7. Your report on the plan should include information regarding the estimated cost, including the cost to the Federal Government, of carrying out the program which you recommend.

In view of the President's desire that this matter receive priority attention, I request that your report on the plan be completed and in my hands no later than September 11, 1964. I would appreciate receiving an interim report within a week on the steps you are taking to meet this request, together with the name of the official of your Department who will provide leadership in this effort. I will designate Lester H. Sheplor as an observer from the Bureau of the Budget to provide liaison with the Department in connection with the preparation of this plan.

I will be glad to discuss the President's instructions with you at your convenience. I am sending a copy of this letter to Chairman Seaborg of the Atomic Energy Commission and to Dr. Horning.

Sincerely,

KERMIT GORDON, *Director.*

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., July 21, 1964.

HON. KERMIT GORDON,
Director, Bureau of the Budget,
Washington, D.C.

DEAR MR. GORDON: Your letter of July 15 asking me to develop an aggressive and imaginative program to advance progress in large-scale desalting of sea water asked that I supply you with an interim report on steps that are being taken to make certain that a final report will be available no later than September 11. This letter complies with your first request and will outline what has been done since the July 8 luncheon and how we propose to proceed to meet the September 11 deadline.

(1) Prior to his resignation, Under Secretary Carr had major responsibility for the Department's program to achieve large-scale desalting plants, its inter-agency relationships and our program for sharing developments with other nations. In carrying out these functions he worked closely with Atomic Energy Commission's Commissioner James T. Ramey in heading up a genuine joint effort by Interior and Atomic Energy Commission in nuclear desalting. The responsibility formerly exercised by Under Secretary Carr has now been assigned to Assistant Secretary Holum who has the responsibility for providing the leadership requested in your letter. Robert Vaughan, who had been Mr. Carr's principal assistant in this effort, has been reassigned to Mr. Holum's office and will work full time in this effort.

(2) John Calhoun, my science adviser, has been directed to devote a major portion of his time to this problem. He will advise me directly and will work closely with Mr. Holum in the discharge of his responsibilities.

(3) Fred MacGowan, Director of the Office of Saline Water, and the various division chiefs within the Office have been directed to conduct an intensive review of the whole program of the Office with appropriate emphasis on large-scale plants and the development of new approaches. Preliminary papers have been prepared and are being reviewed and perfected.

(4) J. Karl Lee, Assistant Chief, Division of Project Development, of the Bureau of Reclamation, has been assigned the responsibility of conducting an intensive review of domestic and foreign water requirements and markets. Office of Saline Water staff members are a part of the effort. The group will maintain liaison with Atomic Energy Commission staff members. Talent from other Federal agencies will be utilized if and when it becomes appropriate and necessary. Appropriate power market studies, as required, will be conducted by the same group with the participation of the Atomic Energy Commission's representatives.

(5) Arthur Jebens, from the Office of the Administrative Assistant Secretary, is reviewing comparable research efforts in other Federal agencies as a prelude to recommendations with respect to appropriate Federal cost sharing at necessary large prototype desalting plants, and appropriate use of research and development facilities within the Federal Government. Atomic Energy Commission participation in both of the efforts will be most appropriate and useful. It has been arranged.

(6) We have considered it highly desirable that we have the views and assistance of competent people from outside of the Government in preparing and completing this review and reorientation of the Department's program for water desalting. Accordingly, we have arranged for consulting service from:

Dr. T. K. Sherwood, MIT.

Dr. Abel Wolman, Johns Hopkins University.

Prof. Rolf Eliassen, Stanford University.

Ted Schad of the Library of Congress is working with the group as an observer. Sherwood, Wolman, and Schad spent Thursday, July 16, with Mr. Holum and his staff. They will return to Washington later this week for further consultations.

(7) To date our country has had little or no experience in coupling dual-purpose desalting and power generating facilities to either conventional or nuclear energy sources (this is one area where the Soviet Union may be moving more quickly than the United States). The Department of the Interior and the Atomic Energy Commission will establish a joint task force to consider means of accelerating our efforts in this field. We will particularly expect this group to study techniques for achieving this coupling and to advise us as to whether or not it will be desirable and necessary to gain experience in this field by actually constructing a dual-purpose unit of a more modest scale prior to attempting coupling of units of the maximum size now possible with established desalting technology. This group will be expected to consult industrial firms, Government laboratories, and engineering organizations with expertise in the field.

(8) In all of our effort between now and September 11, we will not only give attention to need for a major effort to achieve large-scale, dual-purpose nuclear-fueled plants to produce cheap water and power for major markets both domestic and foreign, but we will also make certain that appropriate attention is given to developing the best techniques for converting sea water as economically as possible for smaller markets from smaller plants and for improving the quality of brackish water for inland uses both here and abroad.

(9) Interior and the Atomic Energy Commission are jointly developing an optimum time schedule for relating the development of large-scale nuclear power technology to the development of large-scale desalting technology.

Dr. Hornig and the Office of Science and Technology have been most helpful to this Department in this effort. You may be sure that we will eagerly seek his assistance and that we welcome the participation of Mr. Shepler from your office as an observer.

We will keep you informed as to progress we are making and modifications and additions to the above outlined plan of action as modifications seem appropriate and desirable.

We have developed this proposed program of action with Commissioner Ramey. We have agreed that the Atomic Energy Commission will provide a separate letter outlining in more detail the Commission's plans.

Sincerely yours,

STEWART L. UDALL, *Secretary of the Interior.*

Mr. ASPINALL. Now, Mr. Secretary, in addition to the expanded program embodied in this legislation, do you expect to recommend to Congress the construction of one or more large plants as recommended in your report to the President?

The components that you referred to and the modules that you referred to for development in the near future, will you work on them without advising the committee?

Secretary UDALL. I would say, as I have just indicated, this large plant work will emerge out of these studies that are pending. We expect to consult fully with the Congress. It may even be that we will need additional legislation, and I think that you should be fully advised of all the progress we are making. It does seem to me that maybe we are developing here this morning that there has not been as good liaison as I thought there was in terms of the flow of information. We certainly are not trying to keep any secrets from the country. We do not want to keep any from this committee. We have not been as open in providing information and letting you look over our shoulders. This is certainly what we intend to do and what we would like to have.

Mr. ASPINALL. All right. How do you compare the need for saline water conversion research work with other water resources research? I am thinking, of course, of research related to ways and means for making better and more efficient use of our water from natural sources. Which of these two do you think is more important from the standpoint of meeting the future water requirements of the Nation? Which do you think will give us a better return of the dollars spent?

Secretary UDALL. That is a tough question, Mr. Chairman. This country is, today, making different kinds of investments in water research and water processing. The work that the Public Health Service is doing in the water pollution program in their laboratories is quite similar to ours. We are attempting, basically, to take salts and minerals out of water. They are handling sewage, attempting to take organic matter out of the water and to purify it. So these efforts are closely related.

The new water research program that we have going with the States I think is a timely program. I think it is a good program. We are just getting it started. I think it indicates that this is a good invest-

ment. Of course, this is in basic water research—an understanding of the supplies that we presently have and how to use them better. And I think that the Nation needs a balanced effort. I think that the efforts that we are making in saline water research have been of about the right proportion. I do not see, really, that this overbalances the efforts that are being made in the other fields. In other words, as nearly as I can tell, I would say that we have a pretty good balance in national effort.

Mr. ASPINALL. What bothers me, Mr. Secretary, is that the executive department sends up to this committee, as well as to other committees of the Congress, recommendations for water research programs to carry potable water to the places where it is needed, then we find that the appropriations are cut by recommendations of the Chief Executive and the Bureau of the Budget, and yet here is a program which apparently calls for more, and yet we cannot see any practical operation of the delivery of potable water in economic terms. That is what prompts this question. We cut in one place—I am not speaking personally of it—we cut in one place programs that are authorized and recommended, and yet we come up with a stepped-up program in another place. Do you think this is balanced?

Secretary UDALL. Well, Mr. Chairman, I know what you are referring to, and I think that so far as my Department and so far as I am concerned, I think that we need—and I think that the recommendations that are presently before this committee for new traditional water projects are an indication of our feeling that we need to make a bigger effort all along the line. I think that is my clear answer on that.

Mr. ASPINALL. I agree with that.

Mr. Chairman, I invited Mr. Abel Wolman to appear before the committee, but he is unable to appear. He has certain views set forth in a short letter relative to this particular matter and I would ask unanimous consent that the letter be placed in the record at this point.¹ And after that I would like to continue, Mr. Chairman.

I notice, Mr. Secretary, that you have recently awarded quite a number of contracts covering conceptual design studies of large desalting plants. Would you briefly tell the committee how much these studies are costing the Office of Saline Water and what valuable research data you expect to gain from them? If you wish to answer this question in detail I would ask that you be permitted to do so, and to place it in the record at this point.

Secretary UDALL. I would like to do that in detail.

Mr. ROGERS of Texas. If there is no objection to the request, and there is not, the request of the gentleman from Colorado that the Secretary be allowed to answer the question in detail and furnish in detail the material for the record to be inserted at this point is so ordered. The request is granted.

¹ See p. 25.

(The information follows:)

CONCEPTUAL DESIGN STUDIES

A. 50,000,000 gallons per day

Contract date	Contract No.	Company
Dec. 18, 1964.....	515	The Badger Co., Inc., Cambridge, Mass.
Do.....	513	Baldwin-Lima-Hamilton Corp., Industrial Equipment Division, Philadelphia, Pa.
Do.....	518	Foster Wheeler Corp., Livingston, N.J.
Do.....	519	The Dow Chemical Co., Midland, Mich., and Houston, Tex.
Do.....	516	The Ralph M. Parsons Co., Los Angeles, Calif.
Do.....	517	The H. K. Ferguson Co., Inc., Cleveland, Ohio.
Feb. 8, 1965.....	529	Worthington Corp., Harrison, N.J.
Do.....	525	Allis-Chalmers Manufacturing Co., Atomic Energy Division, Bethesda, Md.
Feb. 17, 1965.....	527	C. F. Braun & Co., Alhambra, Calif.
Apr. 2, 1965.....	528	Applied Research & Engineering Ltd., Co., Durham, England.
Mar. 8, 1965.....	539	Lockheed Missiles & Space Co., Sunnyvale, Calif.
May 4, 1965.....	538	General Electric Co., Burlington, Vt.
May 6, 1965.....	535	The Fluor Corp., Los Angeles, Calif.
Mar. 17, 1965.....	526	Burns & Roe, Inc., New York City.
Apr. 5, 1965.....	514	Aqua-Chem, Inc., Waukesha, Wis.

NOTE.—All contracts are of 6 months' duration.

B. Advanced conceptual design study

Multistage flash distillation process plant of 250 million gallons per day. ORNL contractor. Contract initiated January 1965, to be completed end of June 1965.

DEPARTMENT OF THE INTERIOR,
OFFICE OF SALINE WATER,
Washington, D.C.

REVISED JANUARY 21, 1965

THE 50 MILLION-GALLON-PER-DAY CONCEPTUAL DESIGN STUDY

GROUND RULES

The following ground rules will apply for conceptual design studies under contracts issued by the Office of Saline Water :

General

The study is to cover only the desalination section of a dual-purpose power-water-plant. Design capacity of the waterplant is 50 million gallons per day. It is assumed that the heat source is a fossil-fueled plant. Extraction steam from the powerplant is delivered to the waterplant and hot condensate from the waterplant's brine heater is returned to the powerplant. Electric power generated by the powerplant is made available to the waterplant.

Site

The plant site is considered to be a typical location on the southern California coast. Plot elevation is assumed to be 20 feet. Cost of land, \$25,000 per acre. Excavation is by conventional means, requiring no drilling or blasting. Soil bearing value, 3,500 pounds per square foot.

Sea water analysis and conditions

Sea water temperature is 65° F. Sea water analysis is typical of the Pacific Ocean off the southern California coast. A total dissolved solids content of 33,600 parts per million is assumed.

Product water

Product water shall be delivered to the battery limits at a maximum temperature of 90° F. No water distribution pumping system is to be included within this study, but the product water will be made available at battery limits at a

positive pressure. No on site water storage is to be included. Design will include posttreatment of product water for pacification but will not include chlorination or bacteriological control. Total solids shall be limited to 25 parts per million for product and 2 parts per million for boiler makeup.

Capital charges

Capital charges should include 5,185 percent as an amortization charge (3½ percent interest for 30 years)—0.25 percent for insurance and a figure for interim replacement costs (to be determined by contractor).

Utility costs

Extraction and high pressure steam, available at the plot limits, will have values in accordance with table 1.

Stream factor

A stream factor of 81 percent or 296 days per year has been set for the combined plant. This considers that the waterplant must be capable of operating 90 percent of a year's time at rated capacity with 10 percent for scheduled and unscheduled downtime on the heat source and powerplant. It will be assumed that both plants are baseloaded and steam supply to waterplant will be constant.

Maximum brine concentration

In order to avoid calcium sulfate scale formation, the following limitations upon brine concentration ratios have been established:

	<i>Maximum brine concentration ratio</i>
Brine temperature (degrees Fahrenheit):	
250-----	2.1
290-----	1.15

The first figure above was established by operating experience at the first Point Loma demonstration plant. The second value lies slightly below the solubility limit of calcium sulfate hemihydrate as published by W. L. Badger Associates. This part of the solubility curve is believed to be quite reliable since two OSW contractors are known to have successfully operated near 300°F. on a once-through basis, yet at 310°F. they encountered scaling.

A maximum blowdown concentration ratio of 3 is stipulated to avoid gypsum formation problems. The OSW has evidence that the solubility of gypsum is exceeded at concentration ratios around 3, instead of the values in excess of 4 as reported in the literature.

The above information applies to pH method of scale control. Brine effluent from plant can be disposed of into outfall system.

Plant life

The plant shall be designed for a 30-year life. Interim replacement cost is to be specified by the contractor and included in capital charges.

Instrumentation

Instrumentation shall be provided to permit all normal plant operating functions to be accomplished from the plant control room.

Cost base

Construction cost shall be based on December 1964 construction cost index for southern California. Capital and operating costs shall be based on December 1964 values. Labor rates for operators and maintenance personnel and overhead rate are shown in table 4.

Chemical cost

Chemical costs shall be in accordance with table 2.

Miscellaneous ground and facility costs

Total cost of land, buildings, sea water intake, site preparation, roads, fences, electrical substation, and transmission lines within the boundary limits of the dual-purpose plant will be proportioned between the power and water facilities at rates shown in table 3.

NOTES.—Any questions should be in writing and should be directed to Director, Office of Saline Water, U.S. Department of the Interior, Washington, D.C., 20240 (attention of Mr. E. N. Sieder).

Table 1 of ground rules

Steam cost, brine heater:

Pounds per square inch absolute (saturated):

Cents per
million British
thermal units

72-----	28.3
48-----	25.0
23-----	21.0

Steam cost, air ejector:

Pounds per square inch gage (100° superheat):

100-----	31.8
150-----	34.0

Steam cost, prime steam: 2,400 pounds per square inch absolute, at
1,000° F-----

55.0

Electricity----- 6.2

Electricity, mills per kilowatt-hour----- 6.2

Table 2 of ground rules

Cost of chemicals:

Sulfuric acid (93 percent)-----	per pound--	\$1.15
Chlorine (100 percent)-----	per ton--	130.00
Antifoam-----	per pound--	.42

Table 3 of ground rules

Miscellaneous ground and facility costs:

Land (per acre)----- \$25,000

Submarine pipelines----- 5,600,000

Pump structure----- 300,000

Screens excluding pumps----- 200,000

Total intake, excluding pumps----- 6,100,000

Site development (roads, grading, parking, and fencing)----- 45,000

Common buildings----- 155,000

Air, water, sewage, lighting----- 225,000

Total, all facilities----- 6,525,000

Waterplant is charged with 1/3 of total cost or----- 2,175,000

Table 4 of ground rules—Waterplant operation labor

Position

Annual rate

Plant superintendent----- \$15,000

Assistant superintendent----- 12,000

Plant engineer----- 12,000

Plant chemist----- 10,000

Assistant chemist----- 7,000

Shift supervisor----- 10,800

Control operators----- 8,700

Auxiliary operators----- 7,400

Relief operators----- 8,000

Maintenance supervisor----- 12,000

Mechanical maintenance----- 7,800

Electrical maintenance----- 7,800

Instrument technician (pneumatic)----- 8,400

Instrument technician (electric)----- 8,400

Clerk-stenographer----- 4,500

Timekeeper----- 3,600

Storekeeper----- 6,500

Janitor and laborer----- 5,400

Guards----- 5,650

Payroll burden, 15 percent plus G. & A. at 30 percent.

ATTACHMENT TO GROUND RULES

Answers given to questions raised by contractors :

1. The submarine pipeline terminates at the pit. The pit is open and the sea water pump takes suction from the pit. The suction pressure at the pump inlet is 0 pounds per square inch gage.
2. The cost of the brine effluent outfall is included in the sea water supply cost.
3. The brine heater condensate return should have a pressure of 88 pounds per square inch gage as this pump feeds the boiler feed pump.
4. California State code for earthquakes should be used in the plant design.
5. The price of materials should be U.S. prices, not overseas prices.

LIST OF MAJOR PUBLICATIONS FOR 50-MILLION-GALLONS-PER-DAY CONCEPTUAL DESIGN STUDY

Office of Saline Water Report No. 72: "A Study of Large-size Saline Water Conversion Plants."

Office of Saline Water Report No. 108: "Chamber Geometry in Multistage Flash Evaporators."

Office of Saline Water Report No. 114: Second annual report, saline water conversion plant, Point Loma I, San Diego, Calif.

Office of Saline Water Report No. 116: "Cost Studies of Large Multistage Flash Saline Water Conversion Plants."

Dow Chemical Co., report to Office of Saline Water, July 1964: "An Engineering Evaluation of the Long-tube, Vertical, Falling-film Distillation Process.

Catalytic Construction Co., final report to the Department of the Interior and Atomic Energy Commission, September 1964: "A Study of Desalting Plants (15 to 150 million-gallons-per-day) and Nuclear Powerplants (200 to 1,500 megawatts-thermal) for Combined Water and Power Production."

The Fluor Corp., report to Office of Saline Water (in process): "50 million-gallons-per-day Plant Conceptual Design, Multistage, Multieffect Process."

Computer program: Bechtel Corp., \$50—examples shown in Office of Saline Water No. 116; Catalytic Construction Co., \$100—examples shown in catalytic report.

Program status report—50-million-gallons per-day conceptual design study

Contractor _____ Date _____
Contract No. _____

Description	Schedule for start	Actual start	Percent complete	Schedule for completion	Estimate for completion	Actual completion
Investigations:						
Process.....						
Arrangements.....						
Materials.....						
Components ¹						
Design:						
Process.....						
Arrangements.....						
Components ¹						
Computer:						
Preliminary optimization.....						
Final optimization.....						
Capital cost estimate.....						
Operating cost estimate.....						
Final report.....						

Remarks :

Problem areas :

¹ Components include vessels, heat exchangers, pumps, compressors, ejectors, etc

Mr. ASPINALL. Mr. Secretary, you will remember that I had some correspondence with you in connection with the series of films being produced by the Office of Saline Water. I wonder if we could have a brief report on these films and what they are intended to accomplish?

Secretary UDALL. Yes. We will be very happy to provide that information. The Director could perhaps answer that question.

Mr. DI LUZIO. There was only one film made that I know of and that I have seen. It was intended really for domestic use only, for high schools, and for civic organizations; it shows the water needs pictorially with proper words associated with the film, to explain some of the water problems, what was being done to resolve them, and a brief description of the processes which are at the present time usable. That was the only intent of the film.

Mr. ASPINALL. And how much did it cost?

Mr. DI LUZIO. The figure was \$36,900.

Mr. HOSMER. \$36,900?

Mr. DI LUZIO. Yes.

Secretary UDALL. When was this made?

Mr. DI LUZIO. This was made earlier this year, sometime between January and February.

Mr. ASPINALL. Let me ask you this question: Do you consider that this is an administrative responsibility alone, or do you think that the Congress might have been advised as to what you had in mind before the film was prepared, so that we could have determined whether or not it was a film for instruction purposes, that is, intended only for that purpose, or whether it was in terms of selling a saline water program to the people of the United States?

Secretary UDALL. I, sir, think that it is always best as a policy for us to conduct the best liaison that we can. I certainly agree with you that if a film was prepared that was an attempt merely to propagandize, that this is not something that is sound. I think, on the other hand, that there is a big work to be done in the educational field in the whole conservation area and I think the question is whether what is done is appropriate. We ride herd on the films that we make to see that all fall into the proper category. I hope that we have not slipped. But I certainly think that we ought to consult and confer wherever it is appropriate on these matters.

Mr. ASPINALL. I do not believe that anybody on this committee has seen the film. As I understand it, it is available now if we desire to see it. Is that right?

Mr. DI LUZIO. Yes.

Secretary UDALL. I have not seen the film myself. I would be interested in seeing it.

Mr. HOSMER. The question is not the appropriateness of these films, but the legality of producing them. We talk about cooperation. Under Public Law 87-295 which spells out the authority of the Office of Saline Water these are five in number.

The first is to promote scientific research and studies to develop most economical approaches and methods for converting saline water into water for beneficial consumptive purposes.

Second, to conduct engineering research and technical development to determine by laboratory or pilot plant testing the results of such

research and development in order to develop processes and plant designs to the point to be demonstrated on a large and practical scale.

The third, to recommend to Congress from time to time authorization for construction and operation, or to participate in the construction and operation of a demonstration plant for any process that he determines on the basis of (a) and (b) has great promise of accomplishing the purposes of this act. Such recommendations to be accompanied by a report on the size, location and cost of the proposed plant, including the engineering and economic details.

The fourth, to study methods for recovery and marketing of commercially valuable byproducts.

And the fifth, to make economic studies and surveys to determine present and prospective costs of producing water for beneficial consumptive purposes in various parts of the United States by the leading saline water process as compared with other standard methods.

Where does making a motion picture for high school students come within that?

Secretary UDALL. I would be very happy to get a report on the legal basis for this and report to the committee.

Mr. HOSMER. I think you should.

Secretary UDALL. I am not—

Mr. HOSMER. I know that this was not done under Mr. Di Luzio's regime. But you do not have a license to go out and propagandize to the general public as to the desirability of conservation or anything else. This is the specific charter that tells you specific things to do.

Secretary UDALL. I will be very happy to check into this. I am not aware of the nature of the problem at the moment; that is, the legal problem.

(The information referred to follows:)

STATEMENT RELATING TO THE SECRETARY'S AUTHORITY UNDER SALINE WATER ACT TO PRODUCE MOTION PICTURE

The production of motion pictures is an appropriate exercise by the Secretary of the Interior of the authority granted to him by the 1961 Saline Water Act (75 Stat. 628). The congressional purpose in enacting this legislation was to foster scientific inquiry into the art of converting saline into pure water, a program which it was necessary for the Government to undertake because research and development under private auspices were proceeding at a rate too sluggish to meet urgent national needs. The 1961 act explicitly lists the functions of catalyst, teacher, and publicist among those to be performed by the Secretary—section 2 (42 U.S.C. 1952) providing that the Secretary shall "conduct, encourage, and promote fundamental scientific research and basic studies" and section 3 (42 U.S.C. 1953) that the Secretary shall "coordinate, correlate, and publish information" to advance the development of low-cost saline conversion projects. Because of the effectiveness of motion pictures, both as a medium of information and as a teaching aid, they are clearly among those techniques that the Secretary may employ to carry out these functions.

Mr. ASPINALL. I have one more question of the Secretary. Can you give us the present status of the study you made last year of a desalting plant of Key West, Fla.? Also, the present status of your proposed replacement of the Point Loma plant?

Secretary UDALL. The Key West study which appeared to be very promising a year ago, fell apart later because of the failure at the local level to put together a unified program. There were several different local agencies competing with one another. I think there is

probably need for a better water system down there. I think this could have been a logical place for us to move early in the program when we began building larger plants, but the program was not developed, primarily because of the failure of different Florida entities to decide which group of entities would put together a program and sponsor it. Mr. Di Luzio said that they are moving ahead, or, that one of the entities was moving ahead on its own.

With regard to Point Loma——

Mr. ASPINALL. No. Let us dispose of the situation in Florida first.

Mr. HALEY. If you will yield.

Mr. ASPINALL. Yes.

Mr. HALEY. Mr. Secretary, was one of the things that probably disrupted this program the shortage of the amount of power that would be used, for instance, at certain times of the year down there—there is not a sufficient amount of energy in addition to the normal consumption of the city—was that not one of the principal things?

Secretary UDALL. I think I will let Mr. Di Luzio comment on this.

Mr. DI LUZIO. Mr. Congressman, the original study, as I remember it from reading the files, was for a plant which was too large for the immediate needs. It was too large as proposed. And so was the reactor—the power source—which was originally recommended. A more reasonable figure was about a 2-million-gallon-per-day requirement. Now they have a firm proposal or, rather are working on firm specifications for a plant of about 2.4 million gallons of water, which the city will fund. They are now working on arrangements to get the money to build this plant themselves, using conventional heat—this is where it stands right now.

Mr. HALEY. Of course, I am sure that your agency recognizes the situation at Key West where we have a large defense installation that the present supply of water is about 147 miles away. And in view of this situation developing in South America and in other parts of the country—I think in view of that—that the people in charge of this program felt that it was necessary, with the Defense Department, to see if there was a possibility of making this project possible.

As you all know, we moved from San Diego a plant to Guantanamo, Cuba, some time ago. Because the juvenile delinquent, Castro, with the long beard down there cut off our water supply. We were fortunate in having a plant that we could move to meet our needs.

That is all I have to say about that. Thank you.

Mr. ASPINALL. Before going any further, I do not want it to appear that I have any objection to what was done in Key West. I think that was a necessary operation. I just wanted to get some information. I want to join with the gentleman from Florida in noting that the several groups have been able and are willing to accept it now and go ahead with it.

Now as to Point Loma.

Secretary UDALL. There have been some very recent developments on the Point Loma proposition and I would rather that the Director answer that question.

Mr. DI LUZIO. The San Diego replacement plant is one which we feel very strongly about. It must be replaced to really push the state of the art which will lead to the next generation of multistage flash distillation equipment.

If San Diego I had not been moved we would be making modifications to that plant right now to improve the process and to increase the performance to the optimum.

The original plant was designed for 1 million gallons per day. Changes were made to the plant based on operation experience that raised production to 1.4 million at peak and around one and a quarter million in normal operations. This, of course, has had an effect on the economics of the product water. When the San Diego I was moved to Guantanamo, Cuba, we were left without a plant to try new improvements in this particular kind of process.

We will have to build—for an orderly development of the technology—a plant which is not really a San Diego replacement in terms of technology—it is a next generation flash distillation plant where we can apply new developments, including the use of new kinds of materials, for example, reinforced concrete—we might use reinforced concrete pressure vessels rather than metal.

I do propose to go into this in much more detail in my statement, including some charts and graphs.

MR. ASPINALL. Will this be another demonstration plant for which you are asking authorization, or do you expect to take some of the money that may be authorized in the appropriation this year or next year and go ahead with that, without coming back to Congress?

MR. DI LUZIO. No, sir. We have an understanding with Congressman Rogers that we could come in and discuss and defend the need to build the San Diego plant and the reasons why we must do it. There are three or four different phases of that problem.

One, about \$600,000 in the budget which will expire by June 30 of this year; another \$700,000 will expire in September of this year; plus about \$1 million of Navy Department money for the old San Diego plant, which they want to bargain down to some \$600,000. So the funds will come from those sources.

In addition to that, the demonstration bill, if you read it literally, says "not less than five plants," and the authorization is \$10 million, of which only \$6,500,000 has been spent.

Notwithstanding all of these things, we have a commitment to defend the need for San Diego II to the committee.

MR. ASPINALL. We will go into that further then?

MR. DI LUZIO. Yes, sir.

MR. ROGERS of Texas. Without objection, the letter from Mr. Wolman, under date of May 17, 1965, addressed to the chairman of the full committee, the Honorable Wayne N. Aspinall, will be inserted in the record.

(The letter dated May 17, 1965, follows:)

THE JOHNS HOPKINS UNIVERSITY,
May 17, 1965.

MR. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
House of Representatives, Washington, D.C.

MY DEAR MR. ASPINALL: In reply to your letter of May, I regret to say that I shall not be able to appear at the hearings on May 20 and 21.

My brief comments on H.R. 7092 are noted below, in case they may be useful.

1. The emphasis on desalination of sea water stems from an assumed fresh water crisis. Such a crisis does not appear to me to be supported by the facts of our water availability.

2. The present and foreseeable proportion of desalted sea water to be substituted for fresh water is relatively small, not only because of high unit cost, but because of geographical restrictions in application.

3. The simple multiplication of desalting units does not shed major light on the basic principles underlying the process. Hence, building larger and larger capacity plants, essentially composed of similar multiple units, may provide diminishing returns.

4. The budgetary amounts proposed for the future are in imbalance with respect to the total Federal money expended on all the rest of water resources research. In fact, the latter category obtains amounts almost infinitesimal in comparison. Insofar as the future water requirements for fresh water of the country are concerned, desalting is probably of low general priority.

5. Obviously, modest amounts of money should be spent continuously on basic and applied research on desalting to disclose the physical-chemical and thermodynamic restraints on lowering costs. The bulk of proposed budgeting is not for such purposes, but largely for repetitive units generally of orthodox processes.

Very truly yours,

ABEL WOLMAN.

Mr. ROGERS of Texas. The Chair will recognize the gentleman from Pennsylvania, Mr. Saylor.

Mr. SAYLOR. When Congress started this program, in the act of 1952, and authorized \$2 million for a 5-year program—the members of that committee never dreamed that in 13 years we would have a request from the Secretary of the Interior to increase the authorization to \$200 million. That is somewhere in the neighborhood of a 10,000 percent increase in a period of 13 years. That is the worst inflation that I know in any agency of Government. I think that it is incumbent upon you as the Secretary of the Interior to tell this committee what the United States has to show in the way of progress with the expenditure of somewhere in the neighborhood of \$13 million, and for the \$20 million that you shall ask to expend in the 1966 budget which has been approved, making a total expenditure of \$35 million in the Office of Saline Water? The reason I ask this question is because the people are in doubt. They are asking, "What does the Government have to show in the way of progress? What new systems have been developed in the last 13 years?" I think that is going to have a tremendous effect on this committee as to whether or not we are going to authorize \$200 million which has been requested now.

Secretary UDALL. I think that this whole program can be clearly justified. Any research effort must be justified to the American people. And as I indicated earlier, I think that the program has moved along in an orderly way. This has been a modest program up to this time. During the time period of 1952 to 1965, we have brought the cost of desalted sea water down from \$5 to \$1 per 1,000 gallons and that we are on the verge, we think, of bringing it down further—I think that this in itself is a justification.

The additional knowledge that has been gained, not only in applied engineering development but in the basic properties of water and in the research and development of these different processes, reflects as sound a research program as any in which the Government is engaged.

What it will add to the human welfare is such that I would be glad to debate or defend it against the space program or anything else to date. In terms of its potential to contribute to the human welfare, I mean, now and in the future.

Mr. SAYLOR. Mr. Secretary, this Committee has been quite careful in drafting legislation and saying what you were to do. I am satisfied that not only the present people in your Department but those who have been there since this program started have not followed the dictates of this committee. They have, No. 1, exerted practically all of their efforts toward the conversion of sea water, whereas this committee, in its very beginning, has defined saline water as water that is minerally charged and there are places all over the United States, most in the inland, where the Interior Department has not even scratched the surface in the expenditure of all of this money to try and solve this particular problem.

Now I would like to have you or Mr. Di Luzio tell me what you have done trying to solve the so-called minerally charged water problem.

Secretary UDALL. Well, I want him to comment on it in detail. I tried to emphasize that in my opening statement, that brackish water and minerally charged water is just as important as the sea water problem. I indicated that I thought, in the long run, the development of small or medium-sized plants for inland use is and will be as important or more important than big seacoast plants. Our efforts in the brackish water area have been very substantial. Two of the demonstration plants are on brackish water. I would like Mr. Di Luzio to comment on it briefly.

Mr. Di LUZIO. Just recently we took a look at our activity in brackish waters and we concluded that we must stop extrapolating data from sea water and start doing more basic work on brackish water. Quite a bit of work has been done, but it has not been sufficiently applied.

On the acid mine water problem we quite recently have been working with the Bureau of Mines and the State of Pennsylvania. We have a study now going on to see which of our processes may fit the mine water problem and we may try a pilot plant operation on acid water just as we plan a pilot plant operation on polluted water. I feel sure that the processes that we have spent money on to desalinate water may be applicable to acid mine water or to other waters. Eventually there may be a multiple purpose plant which will do all of these things in one fell swoop.

The economical treatment of acid mine waters will be very difficult. Initially we can provide fresh water to cities on the banks of these mine water polluted streams, and look in greater detail as to how the stream itself can be cleaned up. I am sure that there will be many problems such as the problems of the source of acid waters that will have to be resolved, but we are in that field and moving very rapidly.

Mr. HALEY. Will you yield?

Mr. SAYLOR. Yes.

Mr. HALEY. Let me ask you this question: In letting these contracts I have noticed that from time to time, that is on research, as a layman, that a good many of these contracts cover about the same scope. Let me ask you this question then, who makes the decision on these contracts and who evaluates them to see that we are not constantly having duplication?

Secretary UDALL. This is a very good question. I will explain the details or, rather, Mr. Di Luzio will explain the details to the committee, how the money is spent, how the contract is let. This is a very vital function.

Mr. DI LUZIO. Whenever we receive a proposal which proposes a research project it is evaluated by people in the various disciplines involved. If it is a chemical problem, it would go to a chemical process man, for example.

If we are interested then we will go back to the proposer and ask him to submit more details on objectives, procedures, and costs for the proposed work.

There are two things to be borne in mind. Most all of the proposals that we consider are unsolicited. There are people who may be working in a specific field who think that they have an idea of how they can improve the desalting of water. They submit preliminary information and say that this looks very interesting and that they would like to pursue it—"Are you interested?" If we are interested they come back with a more detailed description. If the proposal has scientific or technical merit, and if it meets OSW program objectives, we negotiate a contract or grant to investigate the process or idea at the laboratory level. If results warrant, they go from that level to the pilot level and then to the larger plant level.

When I came on board I checked with the number of proposals that we had accepted as compared to the percentage of the number we had received. We are now only accepting about 35 percent of all of the proposals we receive. We have as much trouble turning down a proposal as we do in accepting one, because everybody thinks that they have the answer to the desalting problem. That is one of the reasons that most of my highly trained people spend quite a bit of their time evaluating proposals. In some cases we use consultants as well to provide expert advice in specialized fields.

I have appointed a high-level committee of working scientists to provide a thorough review of processes. They are going to sit with me and with my research people, and we are going to review two things: One, the fields of science in which we ought to be participating and, two, what areas of knowledge we need. We just cannot afford to support everything that people want us to support.

We do have a highly selective process of evaluating proposals. As you know, there have been times when we were criticized for turning down a proposal which the inventor thought was the answer to the salt water problem. We have independent people look at it and if they report that this proposal offers nothing new; or that economically it will not be able to compete with other things that we are doing; we turn them down. We are then likely to receive letter after letter from these people who do not get a contract, stating that we are blind or that we do not know what we are doing, but we just cannot fund everything which is offered.

Mr. HOSMER. I am wondering how good a job you are doing in this evaluation? For instance, on page 1 of your table you show that Prof. William Jollie, of the University of California at Berkeley, Calif., was paid \$85 to evaluate research of proposal. What can you get for \$85? That is, in this day and age, from top-level people in relation to a real opinion as to whether or not to go ahead, to put money into this proposal?

Mr. DI LUZIO. It would seem to me that the more important thing to consider would be the technical capability of the professor we have selected for the evaluation.

Mr. Hosmer. That would be about an hour of his time.

Mr. Di Luzio. If it is a highly theoretical proposition that has been submitted it would only take a good technical person just about an hour to see if there are any flaws in the proposal. He would not have to conduct any experiments.

Mr. Hosmer. He would not be able to evaluate dislocation and all of the other things.

Mr. Di Luzio. No.

Mr. Hosmer. You are not familiar with this particular \$85 contract?

Mr. Di Luzio. I am not.

Mr. Hosmer. Do you happen to be familiar with the \$100 payment to Dr. George Murphy—no relation to the Senator—at the University of Oklahoma for the evaluation of research proposal studies in the thermal economics of sea and brackish waters and demineralization process?

Mr. Di Luzio. No, sir; I am not familiar with it.

Mr. Hosmer. Are you still putting out these \$85 and \$100?

Mr. Di Luzio. I am sure that we would if we have the right man—a man who has a reputation in that field of discipline, and if he opened the door for \$100 I do not think we would turn him down.

Mr. Hosmer. Do you get a lot of good help from throwing around these \$100 bills?

Mr. Di Luzio. In some cases we have very good relations with the scientists and in other cases they take after us.

Mr. Hosmer. And then you give them a hundred dollar bill?

Mr. Di Luzio. No, sir. I would never give a man \$100 unless he could produce. If he is the right man for the right job, then in our judgment capability, sir, we would not go looking for a bargain evaluation.

Mr. Hosmer. I want to say that Mr. Di Luzio is one of the best people that we have in the Government, and I have every confidence in him when it comes to running this agency.

Mr. Haley. Will you yield?

Mr. Saylor. I yield.

Mr. Haley. In talking about coming aboard, that would be all right for some of these Navy people, but if we had somebody from the Defense Department who said that we had the situation well in hand, that might make a better impression on me.

Let me ask you this one question: After these contracts are awarded—the Government then provides the facilities for them in the way of laboratories and the like?

Mr. Di Luzio. No, sir, we do not provide any facilities. We may provide the glassware for laboratory experiments and the cost of the small bench scale model or test equipment that they may need. We have not, within my knowledge at this time, ever contributed to the building of any facility anywhere. We just buy an individual's research time and talent for laboratory scale operations. Once a process gets into the pilot plant stage of development we do pay for the construction of the hardware such as our unit at Wrightsville Beach, N.C. or St. Petersburg, Fla.

Mr. Haley. Thank you.

Mr. SAYLOR. To get back to the minerally charged water, I am interested, of course, in the mine drainage. That in a sense is a local problem. However, a national problem that the Office of Saline Water has not even looked at is the treatment of sewage. Here is a situation where we have one agency of the government helping communities all over the United States to build sewage treatment plants, and most are, primarily, treatment plants for the removal of solids. Nothing is done with regard to looking at the water as it flows downstream with regard to the removal of phosphates, nitrates, and other minerals. The effect of hard and soft detergents are creating chemical problems and making the water unusable in thousands of communities throughout the length and breadth of our land. This to me indicates that the Office of Saline Water has just not been cognizant of the real big problem affecting water that this committee had in mind when it authorized and gave the definition of what it meant by the program for saline water.

Secretary UDALL. I want to comment on this and then let the Director comment as well. I could not agree with you more Congressman Saylor. The water conservation you are talking about—the conservation of existing supplies, the careful use, reclaiming and recycling of water—are all important solutions to the water problems that we have in this country.

We have not been in this field as heavy as we should. We are getting into it more and more. The Director will comment on these activities in a moment.

There are those in the Congress, however, who might say that this is the job of the Water Pollution Research Program, and not our job. I do not happen to agree, and we are also getting into it. I would, sir, make it plain that I think the conservation of our existing supplies is a very vital program.

Mr. SAYLOR. Do you care to comment?

Mr. DI LUZIO. I am very, very sensitive to that particular problem since I come from a brackish water section of New Mexico. We have been looking at the use of our processes in the pollution control with the Department of Health, Education, and Welfare. We know that the Department of Health, Education, and Welfare has been making contracts directly with some of the contractors who have conducted work under our auspices, to determine if our processes can contribute answers to pollution-control problems. In my opinion, this is the wrong way to do it. I think that the Office of Saline Water and the Department of Health, Education, and Welfare should work closely together. We have enough data on our processes and enough experimental plants at the Wrightsville Beach test station and some other areas which we might actually operate in a cooperative program with the Department of Health, Education, and Welfare in a polluted stream to see what they will do. There is no better test than actually operating a piece of equipment. We can make all of the paper tests we want, but the real test will be to put some of the polluted water through a plant. We are working on this problem and working on it very diligently, because it is stupid for us to talk about water at 35 cents per thousand gallons in an area where waste water can be reclaimed for 12 to 18 cents per thousand gallons. Quite recently we suggested the use of reclaimed waste to a New Jersey city. They

wanted a brackish water plant to provide approximately 1.5 million gallons of water per day for their city. I asked them what they wanted it for, because they seemed to have surface supplies to meet their needs. They said they needed the desalted water to pump into their wells to increase the hydraulic head, because through overpumping they were getting salt-water incursions. I asked them about their sewage waste. It amounted to millions of gallons. I suggested that they might reclaim some of that water through proper treatment and put their wells on a more reasonable pumping schedule and use a desalting plant to meet peak demands. The shellfish in the area were being contaminated by the polluted water. I referred them to the Department of Health, Education, and Welfare to explore with them the possibility of secondary or tertiary sewage treatment processes. I think that they are going to come back and propose a better program as a result of our comments.

As we pointed out, they should be looking at their problem in a much broader sense than just desalting sea water. A well-planned combination program could save their wells, clean up pollution and reestablish their shellfish industry. These are the things that we are moving into very rapidly.

Mr. SAYLOR. With your background I, certainly, hope that you try to get some imagination into folks as to this water problem, because, frankly, all of the people that I have talked to in government and many others in private industry are still trying to use the same techniques, modernized a little bit, that were used and known 30, 40, 50 years ago. And that if this problem is going to be solved, it is not going to be solved by any of the old-known methods. If there is to be a breakthrough it is going to be with the expenditure of money in research, yes, but also, from the use of brains that will give us new ideas. This is the thing that I think that you should be looking for.

Mr. DI LUZIO. I, certainly, agree with that.

Secretary UDALL. I am glad to have that push from you.

Mr. SAYLOR. Thank you.

Mr. ROGERS of Texas. Mr. Tunney?

Mr. TUNNEY. I have no questions.

Mr. ROGERS of Texas. Mr. Hosmer?

Mr. HOSMER. Mr. Secretary, we must have something to work with in the way of capabilities. Of course, we must have desalting. I have tried to get an answer out of some of you people before. Has there ever been any inventory made as to actually what the requirements are for desalted water—in what areas—and what types of desalting techniques might be most appropriate for them to use, so that we will know, nationally and internationally, what the objectives of our program should be?

Secretary UDALL. We are conducting an inventory of this kind right now. I think the problem that Mr. Di Luzio indicated a moment ago is much more complex and represents many opportunities for desalting technology. We have to look at the problem in the round, as you are suggesting, or we are going to miss a lot of chances to provide answers to difficult water supply problems. But, certainly, we need to sharpen our focus on the "why" of the problem.

Mr. HOSMER. I think so, too. You are going to do that, you say?

Secretary UDALL. We are doing that.

Mr. DI LUZIO. We have three contracts now with very good organizations. The U.S. Geologic Survey has given us quite a bit of information on the brackish water pools in the United States, the communities near these brackish water pools, and the need for the water. The Survey will continue to supply additional information as it becomes available.

Mr. HOSMER. Do you anticipate any increase in demand?

Mr. DI LUZIO. Yes, I will cover that in my statement.

Mr. HOSMER. You have your own internal Government study and three contracts on it?

Mr. DI LUZIO. We have a coordinated effort.

Mr. HOSMER. Do you think that you will come up with something?

Mr. DI LUZIO. We have a coordinated program going on right now with information being supplied by the Atomic Energy Commission, the Bureau of Reclamation, and the Geologic Survey, as a part of a larger program, to ascertain the needs and to determine the size of the plants that are required. This will enable us to put the emphasis where it belongs.

Mr. HOSMER. You are getting somewhere on that eventually then?

Mr. DI LUZIO. Yes.

Mr. HOSMER. How soon do you expect to have it?

Mr. DI LUZIO. We have some information now, but I think in about 6 months we will have a good inventory, and a good basis on which to make decisions on processes and sizes of plants to meet indicated requirements.

Mr. HOSMER. I rather suspect that \$200 million is a premature request until we get that information.

Mr. SAYLOR. Will you yield at that point?

Mr. HOSMER. Yes.

Mr. SAYLOR. I noticed that you said that you were conferring with the Bureau of Reclamation.

Mr. DI LUZIO. We are, also, working with State agencies in New York, Texas, California, and Pennsylvania and the Corps of Engineers.

Mr. HOSMER. Mr. Secretary, do you keep as careful a watch of the Office of Saline Water as I presume you do of all other of your bureaus?

Secretary UDALL. I think it is one of the most interesting, promising programs of the Department. I, certainly, do.

Mr. HOSMER. On May 17 the Office of Saline Water announced six contracts with six different organizations, five of them for \$50,000 and one for \$18,000 for conceptual design studies of large desalting plants. I understand that previous to his announcement 9 other such contracts were made for a total of 15 contracts, also the same thing, totaling almost three-quarters of a million dollars for conceptual designs of large desalting plants. What in the world is the reason for this kind of a multiplication of design studies?

Secretary UDALL. I will let Mr. Di Luzio give you the details on the conceptual design studies.

Mr. HOSMER. You are familiar with it?

Secretary UDALL. I am familiar with it. We have discussed it on a number of occasions during the last 6 months.

Mr. HOSMER. You are enthusiastic about it?

Secretary UDALL. Yes, I am enthusiastic about it. I think that it is a good investment and I will let Mr. Di Luzio tell you why.

Mr. DI LUZIO. This program was initiated prior to my taking the job, but I wholeheartedly support the approach. Perhaps for not the same reason that the contracts were originally let, because there is some misunderstanding as to just what we can expect to get from the conceptual design studies.

So far as the choice of firms that are involved is concerned, we are taking advantage of some of the best brains in the architect and engineering and manufacturing fields.

The short-range program, in my view, is really very difficult as an engineering problem. Firms who have had experience in the petrochemical industry can provide people who know how to cut corners in designing and fabricating a desalting plant, which is really another chemical process. There are ideas in the chemical industry that we need very desperately, because these people have been in business for profit for years and years. We can do things on a theoretical basis or with in-house facilities, but we can not begin to approach the talent industry has developed through many years of experience.

Mr. HOSMER. You say of the petrochemical industry?

Mr. DI LUZIO. The petrochemical industry and the heavy construction industry as well. They are designing and building plants to process materials such as ammonia, urea, and polyethylene. When we talk about a piece of equipment for desalting we are really talking about a similar item.

Mr. HOSMER. I notice that the Lockheed Aircraft Co. is one of them.

Mr. DI LUZIO. This is so, but, Mr. Congressman, they have a tremendous engineering capability and it would seem to me that——

Mr. HOSMER. One of these——

Mr. DI LUZIO. The aircraft industry has done, I believe, such a good job that we should also give them a chance to see what they could do without any preconceived bias as to what the right answers may be, and thereby come up with new and novel ideas such as referred to by Congressman Saylor.

Mr. HOSMER. A \$50,000 contract to come up with some idea, it is like one of these random seminars, except that it is on paper, and the taxpayers pay for it. What it amounts to is a brainstorming technique.

Mr. DI LUZIO. Some of the best work that has been done to develop waste water reclamation membranes has been done by the aircraft industry in connection with the space program.

Mr. HOSMER. That's also a long way from a desalting, a specimen study like this. How do you know that they will not all come in the same?

Mr. DI LUZIO. We are relying on the fact that they are keen competitors. They are all trying to put their best foot forward in the form of new ideas for desalting plants. We are asking for an engineering concept of a combination of things, but we are not asking for an engineering design and specifications.

Mr. HOSMER. All right. Mr. Secretary, let us get precisely the amount of money that has been spent on these things. You are charged with the authority of pilot plant work, byproduct studies, of course. In 14 years' experience, a total sum of \$43,965,000 has been appropriated for this purpose. That is in 14 years, \$43 million plus.

Now you are coming in here for the same purpose and asking for money at the rate of \$40 million a year—per year—almost what you have been able to spend during the 14 preceding years. How does that make sense? How can you accelerate the activities of your office? How does it make economics with the taxpayers then, Mr. Secretary? You have already testified that the research, so far, is beginning to pay off in such degree that during the period of this authority—that this \$200 million—that you should be building some very large plants, which is in addition to the \$200 million, maybe \$30 million at a crack—who knows what it does, how well will Mr. Di Luzio be able to spend that kind of money?

Secretary UDALL. In the first place, we envision that some of this money will go for applied and basic research that will be utilized in these large plants. The cost of hardware is a very important element of the increase we are requesting but I think that if you put this program on a graph, you would find we propose an orderly growth of the program and I think what is envisioned is not—

Mr. Hosmer. Do you mean to say that an orderly part of the program is that in 1 year you have spent the same amount of money that you spent in 14 years?

Secretary UDALL. This has been a very modest program. It gradually has moved upward. I think you would find many of the major research programs of this Government, such as those in the Defense Department and in other departments, have a history somewhat similar to this with regard to—

Mr. Hosmer. This is the Great Society outlook on these things that I cannot quite catch up with as yet.

Secretary UDALL. I think that I can assure you that we are going to spend the money wisely and that we will be able to account for it. I would like for Mr. Di Luzio—

Mr. Hosmer. You do not have any real expectation of getting anywhere near like the authorization? In the past the amount of money that actually has been appropriated—the amount was just over 50 percent of the authorization—and you are not honestly planning on any more now, are you?

Secretary UDALL. We are.

Mr. Di Luzio. One point that I would like to make clear is that on this research and development program for all practical purposes, has only been going on since 1962. From 1952 to 1962, roughly, \$800,000 a year was spent on research. A meaningful research program commenced with the enactment of the Aspinall-Anderson bill of 1961. We are getting to the second phase of the development program which is the hardware stage. We are ready to start now with a 5-year hardheaded engineering program. I am sure that with your experience in the atomic energy field, you know that when we go beyond research and start building practical hardware, that our costs will go up.

Mr. Hosmer. They are, depending upon what order of magnitude you get into. If you scale up a reactor, from 50,000 kilowatts to 10 times that amount you are building an entirely different piece of equipment. When you scale up a desalting process there is, essentially, the addition of more of the same type modules, so that you can get out of one module essentially all of the information you need, and you do

not have to build 10 modules or go into all of the extra expense in connection with the larger model. That is, essentially, the situation, is it not—at least, Mr. Wolman so indicates.

Mr. DI LUZIO. He is right up to a point. The scaling of a large desalting plant does not have benefits to the same degree that scaling-up a reactor may have. There are factors in building a large plant which are very complex from an engineering standpoint.

There is one other point that I would like to make. We are not talking of only the larger plants. Our program, as you will see as we unfold it for you, involves the development, design, and testing of 1, 2, and 3 to 5 million gallons per day plants using other kinds of processes. Not all of the money we are requesting is for large plants. Only 40 percent of the total money we are asking for is going to the short-range program; 40 percent to the intermediate range, which includes research on new materials and new engineering concepts, and 20 percent on long-term research. These breakdowns are in my statement.

Mr. HOSMER. You are going going to build this on the basis of your substantial accomplishments already?

Mr. DI LUZIO. That is right.

Mr. HOSMER. Let us find out what this substantial accomplishment is.

At the hearing in the other body, Mr. Simpson was a witness, the vice president of Westinghouse, who stated that Westinghouse was going to sell its plant off the shelf for producing power at 5 mills a kilowatt, water at 30 to 40 cents a thousand gallons. In addition to that he stated that Westinghouse has not 5 cents worth of benefit from anything that the Saline Water Office has done so far. That they have done it all on their own.

Mr. DI LUZIO. I think that Mr. Simpson will be writing a letter to the Senate committee to correct that misinterpretation. I did not understand it that way. I have a list of the things that they did in the past. They did not design San Diego I. That was designed by Fluor. Westinghouse was the construction contractor.

Mr. HOSMER. Where did the other two units for the thing done at Guantanamo—

Mr. DI LUZIO. On the basis of the San Diego I experience. I think it is more than a coincidence that the two companies which participated in the San Diego I and in the design of San Diego II are the only two firms which would guarantee a turn-key job. It was experience gained in our program that gives them their present competence.

Mr. HOSMER. Westinghouse did not do anything there?

Mr. DI LUZIO. Yes, they did. They erected the San Diego I plant.

Mr. HOSMER. They fabricated it?

Mr. DI LUZIO. Yes.

Mr. HOSMER. The design was that of somebody else?

Mr. DI LUZIO. The design was by Fluor. Then changes were made which increased the capacity from 1 million to as high as 1,400,000 gallons. These changes resulted from ideas which came out of our research program and out of our consultation with other research contractors. We changed the method of treating the water which permitted us to increase the operating temperature from 200° to 250° F.—

Mr. HOSMER. 250°?

MR. DI LUZIO Something of that order. The changes that actually were made, were made on the basis of our recommendations. When Mr. Simpson made that remark I am sure that he did not under the question. He is now writing a letter to Senator Allott which acknowledges that he inadvertently left the wrong impression and he would like to correct it.

MR. HOSMER. He wants to stay in your good graces.

MR. DI LUZIO. I do not think that is the reason. I have known him for years and I am convinced he made an honest mistake.

MR. HOSMER. I was rather shocked to think that you would spend \$½ million—incidentally, at Point Loma—at that point, there has been some talk of putting some sort of a research facility on the west coast, a desalting facility there.

Secretary UDALL. This is under consideration right now.

MR. HOSMER. You have not made any decision as to where you will put it?

Secretary UDALL. No. The most promising site appears to be San Diego.

MR. HOSMER. There is, also, something that come up about brackish water recently. Is there anything definite on that that you can tell us?

MR. DI LUZIO. No, sir. We are looking at two possible sites where we now have brackish water plants, because they have power and steam available. There is one in New Mexico and one in South Dakota.

MR. HOSMER. Do you intend to put in research centers?

MR. DI LUZIO. When we say research——

MR. HOSMER. Like at Point Loma?

MR. DI LUZIO. Not to that extent.

MR. HOSMER. On the west coast you are working with the Department of Water Resources of the State of California. If you do put in research facilities out there, are you going to keep control of it or will Mr. William Warne of the State control it?

MR. DI LUZIO. We are keeping control of it.

MR. HOSMER. You will have to work hard to do it.

MR. DI LUZIO. We will make a college try.

Secretary UDALL. We usually manage to hold our own with the State of California.

MR. HOSMER. Yes. How are you holding your own with respect to Dr. Zarchin with the freezing process that he has a lot of patents on? Do you have to pay him royalties to fool around with the freezing process?

MR. DI LUZIO. I think you know that I was with Fairbanks Morse at one time.

MR. HOSMER. I had forgotten.

MR. DI LUZIO. At the time that I took this position the contract with Colt was already underway. The Zarchin process was a contribution made by the State of Israel to the Colt Co. which was organized for the development of the process. One-half of the process was owned by the State of Israel, and one-half by Fairbanks-Morse. I was vice president of engineering for Fairbanks-Morse at the time the initial agreement between F-M and Israel took place.

We really gave the process a going over. The Office of Saline Water is not paying any royalties to Zarchin. We are going to test

the process, because it still has considerable promise. It did not materialize in the time frame that was originally planned, for one simple reason. The phenomenon was good—the process had no scientific bugs in it, but we just did not know how to build a compressor to move the vapor fast enough.

This is a good example of why we have to build the hardware to test a process. On paper the Zarchin process looked wonderful, but when we tried to build the compressor to move the tremendous quantities of vapor involved we could not do it.

The compressor had to move at supersonic speeds, and it kept breaking up. When I left the company the problem was being solved by an aerodynamist, rather than a mechanical engineer.

The aerodynamist who finally designed that compressor was really an aerospace man. This is the kind of talent that we can find in the aircraft industry.

Mr. Hosmer. These 15 contracts that I mentioned to you previously, is there any way whereby you can deal with the MWD along the same line?

Secretary Udall. They are related. The MWD agreement is for an engineering and economic feasibility study.

Mr. Hosmer. What corporation?

Secretary Udall. Bechtel.

Mr. Hosmer. How does it happen that Fluor gets only \$18,000 and the others get \$50,000?

Mr. Di Luzio. One reason is that we are pennypinchers. Fluor has completed studies for us in almost identical areas. We did not feel that it was worth \$50,000 to get information from them which they already had developed under previous contracts. The price was negotiated at \$18,000. This covered the additional work that they had to do.

Westinghouse is doing it for nothing.

Mr. Hosmer. You have three different firms?

Mr. Di Luzio. The three firms that are working on the economics of water are Metcalf & Eddy, Black & Veatch and Southwest Research.

Mr. Hosmer. I understand that the Italians are looking over your property. Are you going to make some kind of a deal with them, the same as you made with the Israelis and the Russians?

Mr. Di Luzio. I cannot answer that. They have only asked to be brought up to date on current technology.

Mr. Hosmer. You are giving it to them, is that it?

Mr. Di Luzio. It is open to the world.

Mr. Hosmer. There is some concern by my constituents about giving away this stuff to foreigners all of the time. What is the value of this kind of thing?

Secretary Udall. President Kennedy and President Johnson and I am not sure, President Eisenhower, too, before them, indicated that because the solution of this problem would be helpful and beneficial to the welfare of other peoples that we were willing to share our technology and the benefits of our research with anyone who was interested. This has been a rather constant policy and will continue to be so. I think it is a very sound policy for a program of this kind, which is essentially directed toward enhancing the resources of the

world. There is a worldwide interest in the project, as indicated already by the interest in the conference.

Mr. Hosmer. As to this information that you are getting out of the Russians by way of exchange, I gather from this testimony, Mr. Secretary, that you got a look at a million-and-a-half-gallon-a-day plant and they told you that they were going to have a reactor. Have you or are you going to receive studies that they have made?

Secretary Udall. If you have not seen them, I would like you to see the report of our team that went over there. It is available.

Mr. Hosmer. I am just trying to get something in the record, to capsulize it.

Secretary Udall. We got considerable information. It was felt that the exchange was a very fair and open one. We have a pretty full understanding of what they are doing—what their techniques are.

(The information referred to follows:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., December 2, 1964.

Memorandum to: The Secretary.

From: Science adviser.

Subject: Preliminary report on desalting delegation trip to the Soviet Union.

This is in response to your request for a brief summary of my impressions about the recent trip of the desalting delegation to the Soviet Union.

In summary, I would say that the Russians offer us keen competition in the desalting field. Although they still have much to learn from us, it is obvious that we can learn also from them. They have a continuously operating, scale-free distillation unit producing 1.5 million gallons per day for a new city and they will double this soon. They have definite plans to couple a desalting unit to a nuclear reactor at this same location. They have focused their effort upon the specific job of desalting Caspian Sea water and have shown engineering skill in achieving a workable solution. It does not follow that their solution is workable, however, for ocean water or for the competitive economic conditions of our country.

In more detail, the following points are enumerated:

1. We saw a broader spectrum of research and development than I had anticipated. Their work concentrates on desalting of Caspian Sea water with a minor amount of attention given other brackish waters. There is no research on ocean water.

Their efforts parallel ours in many respects, although they reported no work on freezing methods and they are just beginning work on reverse osmosis. A large amount of their effort seems to be directed toward the prevention of scale and to the development of membranes for electrodialysis.

In some respects, their research was routine and they reported results to be anticipated by the reading of our literature. In other respects, their approach is imaginative. They have a real accomplishment, in my opinion, in the development of a seeding process for the prevention of scale during distillation. We have done research on the seeding method, but the Russian approach is different. They add seeds in high concentration to produce a slurry that is recirculated within the evaporator. No additional seed need be added during the operation. In this way, they have carried on routine evaporation of Caspian Sea water at Shevchenko for almost a year.

The Shevchenko distillation installation is of 1.5 million gallons capacity, using steam from an electric power station nearby. It provides the city with its water supply. The city is said to have about 20,000 inhabitants, mostly construction workers and their families. The Russians have immediate plans to build a duplicate unit alongside the first one. In the same city, they have started construction of a 350-megawatt fast-neutron reactor to which ultimately will be coupled a desalting unit. The nature of the desalting unit is yet to be determined from the performance of those units now operating and from further experiments.

Also at Shevchenko, we saw five or six different pilot plant units. This installation can be thought of as being parallel to our Wrightsville Beach Station. They are making a full-scale test of a single vapor compression unit similar to those we have at Roswell.

The Russians have also concentrated upon softening of Caspian Sea water by thermal methods so that it can be used directly as boiler feed water even though the salt content has not been removed. This appeared to be working successfully in a 300,000-gallon-per-day unit at a powerplant installation north of Baku.

2. We received a very hospitable reception and first-class treatment. At each place we visited, the technical exchange was open and free. The Russian technologists were well prepared and at each location we listened to the delivery of detailed scientific papers. They placed at our disposal an airplane (similar to our Electra) with a full crew for our trip from Moscow to Sverdlovsk, Alma-Ata, and Baku. There were no incidences that reflected any sort of friction.

3. Our host was the State Committee for the Utilization of Atomic Energy of the U.S.S.R., and during our final meeting they indicated that the Russian implementation of the recently signed desalting agreement would be handled through this Committee. Dr. Petrosyants, Chairman of this Committee, held the initial meeting with our delegation. Dr. Sinev, Deputy Chairman, chaired the final meeting. During our tour of institutes and site locations throughout Russia, we were accompanied by Dr. Kolitchev, head of the Chemical Research Section of the State Committee for the Utilization of Atomic Energy. Kolitchev apparently is responsible for the allocation of funds to various research institutes working on aspects of desalting, particularly as they apply to the decision for a desalting method to be coupled with the reactor being built at Shevchenko.

4. We visited six scientific research institutes that were doing work on desalting. In some cases, this work seemed to overlap. We also visited two atomic reactor sites at one of which there was a physics research institute; a distillation desalting unit producing 1.5 million gallons of water a day; a powerplant installation producing scale-free boiler feed water; and several pilot plant installations at which testing work was proceeding on new methods for desalting water. It is difficult to estimate the total magnitude of their desalting research and developmental effort, although it is larger than I expected. I guess the manpower level and dollar expenditure level to be about half of our OSW program.

5. We took the Russians a copy of the recent Report to the President on Desalting and they had translated it before our final meeting. Dr. Sinev commented that the date of the report followed the visit of the Russian delegation to the United States and he thought that they could take some credit for the nature of the report.

They asked a number of questions concerning Atomic Energy Commission plans to produce a large organic-cooled reactor. The AEC representatives promised to send such published information as was available.

They expressed a deep interest in the international desalting symposium which we have scheduled for Washington, D.C., next fall and are interested in participating extensively. They also suggested the possibility of a joint U.S.A.-U.S.S.R. publication on desalting through the medium of the International Atomic Energy Agency. We agreed to explore this possibility.

They suggested the exchange of scientific films on desalting and we agreed that each would prepare lists of films that were available for exchange. We also promised to send to them a list of publications on desalting available through the Office of Saline Water.

Both sides agreed that we should now anticipate exchanges of individuals who could profit from discussion on specific research ideas. It was suggested that each side would outline topics on which further detailed scientific exchange should be made.

The Russians were very interested in our approach to economic analyses and to our evaluation of economic parameters. They also asked many questions about the criteria which we are using for making decisions on expenditures of funds for research in various methods of desalting.

JOHN C. CALHOUN, Jr.

Mr. HOSMER. Did they invent desalting?

Secretary UDALL. No, I think that they are actually latecomers in the field but are moving pretty fast, because they have a water problem in the Caspian Sea area.

Mr. Hosmer. I thought that they might have invented this, too. They have invented everything else.

Secretary Udall. Perhaps.

Mr. Di Luzio. Congressman Hosmer, Mr. Zarchin was born in Russia.

Mr. Hosmer. How are you going to get along, Mr. Di Luzio, on this \$20 million that you were going to get this year, having lived in the rich blood of \$40 million a year anticipation?

Mr. Di Luzio. I have not really lived it.

Mr. Hosmer. Will it hamper your research and your progress in this program, will it slow it down to the extent that our international peace weapon arsenal will be stunted?

Mr. Di Luzio. Are you talking about the \$22 million for 1966?

Mr. Hosmer. Yes.

Mr. Di Luzio. I think that the engineering program as we have laid it out can make very effective use of that money. We have had to slip the cost of the large models that we would like to build into the 1967 budget.

Mr. Hosmer. You plan to spend \$40 million in 1967, even though you are spending only \$20 million in 1966?

Mr. Di Luzio. I do not know what the 1967 budget will be, because we are still working on it. I do not think that we will spend \$40 million on an even keel during the 5-year program. It will peak as a result of hardware purchases. The biggest increase will result from the cost of the hardware.

Mr. Hosmer. The only thing that you purchase hardware for is the pilot plant and laboratories.

Mr. Aspinall. The legislation that is proposed would mean that the Department will have the authority to seek to build modules and component parts. These are the terms under which the new authority for the extended operation would be had.

Mr. Hosmer. Module and components. That is not plants, is it?

Mr. Di Luzio. They are test bed devices.

Mr. Hosmer. Do they use it in the work?

Mr. Di Luzio. At the test facilities and not in actual plants.

Mr. Hosmer. So that we are not to get the idea that they are massive installations.

Mr. Di Luzio. They can be massive. One module could be as large as 17 million gallons per day for hydraulic studies and 2.5 million gallons for experimental evaporator systems.

Mr. Hosmer. That is the question that we were talking about before, about the nonnecessity of going further into the module in the large demonstration plants, was it not? You rather endorsed that thing?

Mr. Di Luzio. If I understand your question correctly, what it means is that prior to the commitment of substantial funds to build a large plant we would like to run a section or a segment of the large plant to see whether or not our economic and engineering understanding is good enough to be committed to a final design. That is what we propose to do.

Mr. Hosmer. This means, then, that we are not going, as the Secretary indicated, to have repeated requests for authorizations for large pieces of hardware?

Mr. Di Luzio. We envisioned—

Mr. Hosmer. I want to get some idea on both sides of this program that you will come up with.

Secretary Udall. Let me defend myself here. What I was intimating is that we might find ourselves doing what Mr. Di Luzio just described. In addition to that, if your southern California people feel and can make a case that we ought to participate to some further extent in terms of a contribution to a plant that they would build, we might do that. I do not know whether we could justify it, because I do not yet know what the results will be. But obviously, if the Congressman from southern California does not think that it is a good idea, we might not do it.

Mr. Hosmer. Thank you.

Mr. Rogers of Texas. Under the rules of the committee it is scheduled to adjourn at this time, at 11:45 o'clock. It is anticipated that we will meet this afternoon. I think at 2 o'clock. Will any of the other members have questions of the Secretary?

Mr. Reinecke. Yes, of the Secretary.

Mr. Rogers of Texas. Will it be short?

Mr. Reinecke. Yes.

Mr. Rogers of Texas. Very well.

Mr. Reinecke. This report that I have a copy of has several charts in it and they are not in the copies that were delivered to the committee. I wondered why the committee did not get the full report.

Mr. Di Luzio. The other was the AEC's report to the President.

Mr. Reinecke. The committee is not going to get that one?

Mr. Di Luzio. I did not mean that. I mean that one part was Interior's report to the President. I do not know why the committee did not get the other.

Mr. Reinecke. May we have copies of those so that we will have full information?

Mr. Di Luzio. We can certainly arrange that.

Mr. Reinecke. In this report in several places, as has been brought out in the testimony, you have indicated new approaches must be found before we are going to get water at a nominal cost. In this same report you indicate that in your 1966-67 program that 41 percent of the money will be spent on the distillation process. This does not sound like any breakthrough. If we admit that we need a breakthrough, why are we spending 41 percent of our money on that?

Mr. Di Luzio. Forty-one percent of the total amount has been allocated to distillation. Of this, 17 percent reflects new ideas, new engineering, and new technology. The rest is hardware. There is nothing new under the sun. Nature has been doing all of the things that man has been trying to emulate. In that sense, there is no new process. In engineering and designing plants we try to achieve this phenomena at the lowest possible cost. This is where our job lies. The distillation technology is far from ultimate development. There are matters such as higher temperatures, better pretreatment, in fact, all kinds of things that we have to do to really bring distillation down to the very cheap water that we require.

Mr. Reinecke. And that research is what?

Mr. Di Luzio. Some of the research we are doing is on membrane processes. There are many phenomena that we are looking at very carefully so that we do not miss a bet. There is no single plant that

will answer all of the water problems or even face up to the chemistry necessary.

Mr. REINECKE. You also show 9 percent for other purposes and 14 percent for reverse osmosis and the like.

Mr. DI LUZIO. Yes, and 30 percent for research, and 6 percent for administration.

Mr. REINECKE. And this other is not in building plants?

Mr. DI LUZIO. No, sir. We have charts in my presentation that will break that down in detail.

Mr. REINECKE. Very well. Mr. Secretary, you indicated that we still do not have the answer to the problem and yet it seems to me that the public relations is far ahead of the technology.

Secretary UDALL. Let me comment on that, because when I say that we do not have the answers, we are talking about a very broad program with many facets to it. We think we have enough of the answers. I think some of the industry people do, too, but we hope within the next year or two that we can begin work on the large plants, so that your answer has to be "Yes" and "No." We are going to need a very broad-gaged, wide-ranging program in order to move the program forward on that same broad front that we have been working on during the last 5 years.

Mr. REINECKE. Congressman Hosmer indicated earlier about what the anticipated deficit might be. You mentioned an inventory program that you were working on as to the water requirements. I read a report which I do not have with me this morning put out by the Department that indicated that the deficit in the year would be 12½ to 13 percent—are you familiar with this?

Secretary UDALL. Yes.

Mr. REINECKE. Is not this anticipated deficit one in amount that we could by means of conservation and other reclamation projects fill without ever getting into the salt water problem?

Mr. DI LUZIO. I would like to answer that in two different ways. Averages are not very good—they are not a very good statistical system of data to start a program with. You may have a community that has no water, and another community that has twice what it needs. We now have communities that either have no water available or have bad water available which ought to be treated and made potable, so averages really do not make sense.

Mr. REINECKE. That was a national average.

Mr. DI LUZIO. Yes; it was a study which also reported that the east coast and Midwest America seemed to have sufficient water although they had some problems for a number of years. The west coast is in trouble. Basically, it is because of the longer distances that they must transport the surface flows of water. This will eventually lead to proposals for the diversion of the Columbia River, and all kinds of other ideas on how to get water down into the Southwest.

Mr. REINECKE. I am not certain whether the objective of this program is one of academic study or of a very practical low-cost, water-producing supply system. Would you clarify that objective for me?

Secretary UDALL. It has a very practical purpose and has had from the very beginning. That is the reason that Congress had us put in these demonstration plants. We are moving down the road, I hope, toward a whole series of plants. In the long run I think the whole concept has been very practical. Naturally, academic research and other kinds of research are a very important part of a program of this kind.

Mr. REINECKE. What do you consider the principal objective to be so far as the cost of the water is concerned?

Secretary UDALL. I think that we will regard it as a big breakthrough if we can bring the cost of a thousand gallons down to 30 cents. We think it will go well below that before we are through, but if we can do that in the next 3 or 4 years, this would be a very significant achievement. I think that this would justify—this itself—every cent that the Congress has appropriated up to this time.

Mr. HOSMER. You are not at that price now?

Secretary UDALL. No.

Mr. REINECKE. On the 30-cent figure, it seems to me from other studies you are going to have some very, very difficult times, even under ideal conditions, getting it down. There is a lot of very fundamental engineering research that must be done before you ever put the first nut and bolt together and until we can prove that there is that actuality or possibility in fact, a process that will produce water at this price within the practical limits that we are talking about.

Mr. DI LUZIO. I would agree with you 100 percent. When we are not sure of the thermodynamic cycle that you are talking about, I think that we would hesitate and go back for more technological data.

Mr. REINECKE. If we do not have that, why are we spending this money?

Mr. DI LUZIO. The data that we have obtained from San Diego I indicates very clearly that with certain additional refinements, this kind of a concept in arrangement which produces power or steam at a certain price, can produce water at 30 to 35 cents. We are sure of that.

Mr. REINECKE. I would like to have a personal interview with you on the facts of that plant.

Mr. DI LUZIO. I will be very happy to have that.

Mr. REINECKE. I do not think that we will ever get within that realm unless we are using unrealistic costs for power.

Mr. DI LUZIO. We cannot afford to do that. We have to be very realistic about our cost estimate. We cannot reduce the cost of power. The cost of power will be whatever it is as it comes out of the generator. We have been involved long enough in the Atomic Energy Commission program, as the Congressman knows, to be confident that the estimated cost of steam from reactors is within the ball park. That is the only factor that we need to know—the cost of the energy. I think we have this pretty well pinned down.

Mr. REINECKE. It seems to me that we will be spending a lot of money foolishly until we know what we are working on, that it is obtainable.

Mr. DI LUZIO. I could not agree more.

Mr. REINECKE. You mentioned that you had appointed a committee of scientists. Would you mind giving us their names?

Mr. DI LUZIO. It is in my statement and it will be submitted for the record.

Mr. REINECKE. Thank you.

Mr. ROGERS of Texas. The first witness this afternoon will be Mr. Ramey of the Atomic Energy Commission. Do you have anything further?

Secretary UDALL. No; I do not.

Mr. ROGERS of Texas. We will stand in recess until 2 o'clock this afternoon.

(Whereupon, at 12 noon the subcommittee adjourned to reconvene at 2 p.m. of the same date.)

AFTERNOON SESSION

Mr. ROGERS of Texas. The subcommittee will come to order.

I believe our first witness this afternoon is Commissioner James T. Ramey, of the Atomic Energy Commission.

Commissioner Ramey, if you come forward, we will recognize you.

STATEMENT OF HON. JAMES T. RAMEY, COMMISSIONER, ATOMIC ENERGY COMMISSION; ACCOMPANIED BY WILLIAM A. WILLIAMS, JR., CHIEF, DESALINATION BRANCH

Mr. RAMEY. Mr. Chairman, I have with me Mr. William A. Williams, Jr., who is Chief of our Desalination Branch in our Reactor Development and Technology Division.

I appreciate the opportunity to appear before this Committee to review briefly what the Atomic Energy Commission is doing to make possible the use of nuclear energy for desalting seawater. It is a pleasure to be able to discuss the AEC's activities in this area with you today.

For nearly two decades, the U.S. Atomic Energy Commission, in cooperation with industry and with the encouragement of Congress, has been developing nuclear systems for peaceful purposes. During the past decade, in particular, we have devoted considerable effort to the advancement of reactor technology for the generation of electricity in the United States and the world. Our program goal of economic generation of electricity by nuclear means is nearing realization in many areas of the United States.

The potential of tying in nuclear energy with the desalting of seawater was recognized as far back as 1955. Dr. R. Philip Hammond, now at our Oak Ridge National Laboratory but then at Los Alamos, indicated that the heat from nuclear reactors could be used to distill seawater, and that the unit cost of the energy would decrease significantly with the increasing size of nuclear plants.

In the late 1950's, a development and design effort related to process heat application for paper manufacturing and food processing resulted in congressional authorization for a low temperature process heat reactor. Due to the small quantity of energy required by process heat users, no potentially economic process heat application was found.

Initial plans for a sea water distillation plant utilizing a nuclear heat source were formulated in 1959 by the Department of the Interior and the Atomic Energy Commission. This plant contemplated the

construction of a small experimental process heat reactor coupled to a 1-million-gallon-per-day demonstration multistage flash sea water distillation facility.

Unfortunately the reactor portion of the project did not go forward because of siting difficulties. Subsequently, the Department of the Interior built what proved to be the highly successful Point Loma distillation plant at San Diego with a fossil fuel heat source.

Interest in nuclear process heat for desalting did not increase again until recently when the scale up of nuclear powerplants made energy cost less expensive.

In this interim period, the Commission's civilian nuclear power program made substantial progress in furthering the technology and construction of large size light water cooled nuclear powerplants, as well as smaller prototypes involving more advanced concepts.

An indication of this progress is reflected by the fact that five light water cooled nuclear powerplants over 400 megawatts electrical in size are currently under contract for construction with power costs from 4 to 6 mills per kilowatt hour. Also significant is the construction of power conversion facilities for utilizing energy from the new production reactor at Richland, Wash. This facility will be capable of generating 800 megawatts of electricity and is scheduled for completion late this year.

In 1962, Dr. Hammond recalculated some of his earlier work and published his results in conjunction with the Oak Ridge National Laboratory. This work attracted the attention of the Presidential Office of Science and Technology. Dr. Wiesner, then the Director, appointed an ad hoc task group to investigate the thesis that energy costs from very large reactors would be low enough that fresh water could be produced from sea water economically by distillation processes. Staff of the AEC, the Federal Power Commission, and the Department of Interior—including the Office of Saline Water and the Bureau of Reclamation—were on the task force. The late Commissioner Wilson, and I, served as AEC representatives on this panel. We had meetings for a little over a year and issued our final report in March of 1964.

Last July, as you know, President Johnson requested the Department of the Interior, in close collaboration with the AEC, to prepare a plan for an aggressive program for the large scale desalting of sea water. Again Interior and AEC staff worked in close cooperation to develop the report to the President on a program for advancing desalting technology, which was released in late October.

The AEC's program for developing suitable energy sources for desalting, as set forth in the Report to the President, has two major areas of endeavor.

The first one is to provide appropriate nuclear energy sources to meet desalting needs during the next 5 to 15 years. We will do this by determining the most efficient methods of combining proven nuclear reactor systems with desalting plants.

The other, which is a longer term program, involves the development of engineering and economic data, and the operation of suitable prototype plants, which will permit us to determine the best nuclear reactors for the longer range use as energy sources for desalting plants producing several hundreds of millions of gallons of fresh water per

day. This latter part of our program is aimed at developing engineering and economic data by the midseventies to determine the optimum nuclear energy sources for large scale desalting plants beyond 1980.

With respect to our near-term program, we now have nuclear powerplants, commercially available which can provide energy for water desalting plants in dual-purpose installations. However, no practical experience has been obtained in the design, construction, and operation of reactors for this purpose, particularly in regard to the coupling of the two systems. Therefore, investigations of various aspects of reactor and powerplant design are being conducted to determine the best sizing, operating characteristics, and economics.

We are also conducting engineering and economic studies for specific locations jointly with Interior. These include the joint studies we are conducting with the Metropolitan Water District of California and with the Government of Israel. General systems analysis are being conducted at our Oak Ridge National Laboratory and by selected contractors.

We are also endeavoring to establish the advantage of applying current reactor technology in modified systems designs to provide energy at temperatures directly applicable to single purpose water distillation plants.

To meet the long-term needs for nuclear energy sources for large-scale desalting plants, we are investigating the potential of reactor concepts ranging in size from 3,500 to 10,000 thermal megawatts of heat.

The feasibility of scale-up to large sizes, the economics of such systems, and the special design advantages resulting from dual-purpose applications are being examined.

The reactor concept which we have identified as the leading candidate for use in the long-range desalting program is the heavy water organic-cooled reactor. This reactor's prospects for producing very low cost energy, for efficient use of nuclear fuel, and for practical use in large single unit sizes makes it promising whether used in power only or dual-purpose plants.

Our current planning for our civilian nuclear power program includes a 1,000-thermal-megawatt prototype of this concept for operation in the early 1970's. This prototype will be designed to produce about 300 megawatts of electric power, and is expected to demonstrate the technical feasibility of this particular concept.

The next logical step would be the combining of a heavy water organic-cooled reactor, or an improved reactor concept of another type, with a desalting facility to produce both electric power and fresh water. Our present planning calls for the construction of a reactor of about 3,500 thermal megawatts, with an output of electricity of about 500 megawatts electric and 300 million gallons per day of water. This plant would begin operation in the 1975-78 time period.

I might mention here, Mr. Chairman—of course before we have selected the particular reactor concept, we would have reviewed all potential reactor concepts at that time, and other heat sources for that matter, and select the best reactor that we thought was potentially useful in the large sizes.

We have initiated a study of the siting and operational problems of very large size nuclear energy systems for dual-purpose application. We are also investigating the technical feasibility and economic advantages of combining other industrial processes with desalting plants to improve the overall economics of the use of nuclear power.

Now, as to the international program: President Johnson, on several occasions, has expressed his support for sharing the benefits of American desalting technology with other nations. For example, in a message to the delegates to the Third Geneva Conference on the Peaceful Uses of Atomic Energy last summer, he said:

Our Government is proceeding with an aggressive program of nuclear desalting. What we learn in this program will be shared with other nations. Already we have begun cooperative exchanges with Mexico, with Israel, and with the Soviet Union. Today I invite all of you to join with us in this enterprise.

The International Atomic Energy Agency —IAEA—has been the focal point for the AEC's international cooperation in this field. The IAEA, an international organization established in 1957 to promote the peaceful uses of atomic energy, and also to control the military diversion of peaceful atomic energy materials, has taken an active role in evaluating the possible application of nuclear energy to desalting.

In early 1963 the IAEA convened a panel to advise it on the status of water desalting technology and on the general merit of using nuclear reactors as the energy source for desalting plants. Over the past 2 years, five panel sessions have been held, and representatives from about 25 countries have attended. It has been my pleasure to work in close collaboration first with former Under Secretary James Carr and later with Assistant Secretary Kenneth Holum as the U.S. representatives to these sessions.

We have been reviewing the needs and potential for nuclear desalting in Israel, Tunisia, and the United Arab Republic in cooperation with those countries.

The United States and Israel have completed a preliminary survey of Israel's water and power needs, and a detailed engineering and economic study is in progress. The preliminary survey indicated that a dual-purpose nuclear plant producing 100 to 150 million gallons per day and 175 to 200 megawatts electric may be economically attractive for Israel's power and water needs.

Discussions are being held regarding a proposed cooperative study with Mexico in which both the AEC and the Department of the Interior would participate, and which would be conducted under the sponsorship of the IAEA.

A technical team from Italy is presently visiting U.S. facilities and preliminary discussions regarding possible cooperation on desalting have been held.

We are participating in a program with the U.S.S.R. for an exchange of technical information in the desalting field, including the use of nuclear energy.

To insure that our international desalting activities are consistent with U.S. foreign policy objectives, the AEC, along with the Departments of the Interior and State and other appropriate Government agencies, is represented on an Interagency Committee on Foreign Desalting Programs.

Now to the AEC organization for desalting: The development of nuclear energy for desalting has strong Commission support. Responsibility for policy-level coordination has been retained at the Commission level. A Desalination Branch has been established in the Division of Reactor Development and Technology to handle the day-to-day administration and implementation of the AEC's program. The Desalination Branch Chief reports to the Assistant Director for Civilian Power, who is responsible for developing civilian nuclear power reactors, and coordinates nuclear desalting technology with the technology arising from the other reactor development programs.

The Oak Ridge National Laboratory has been assigned a major role in the AEC's research and development program for the application of nuclear energy to desalting. An experienced group of scientists and engineers is working at Oak Ridge in several of the areas which I mentioned earlier. We are also utilizing Oak Ridge National Laboratory as a technical extension of the Desalination Branch in conducting the overall AEC program.

The talents of our other National Laboratories and industrial contractors will be used in performing part of the work in our program.

The AEC and the Office of Saline Water recently completed arrangements for the use of the Oak Ridge National Laboratory and the engineering capabilities of the Oak Ridge gaseous diffusion plants, in the desalting technology work, also. Under this arrangement, work will be performed for the OSW on intermediate and large-scale desalting plants.

In conclusion, we in the Atomic Energy Commission are glad to participate in the joint nuclear desalting program. We are working effectively with the Department of the Interior in planning and initiating a coordinated development effort. The program which we are undertaking, when taken together with the program of Interior, provides a realistic path toward our objectives. With the continued support of the Congress and its appropriate committees our objectives can be achieved.

Thank you, sir.

Mr. ROGERS of Texas. Mr. Commissioner, in reference to the term "nuclear desalting technology"—now, isn't that confined primarily or basically, let's say, to energy itself? I mean there is no process of desalting having to do with radioactive particles or things of that kind. It all has to do with the energy source, doesn't it?

Mr. RAMEY. Yes, sir, that is correct.

Mr. ROGERS of Texas. Mr. Tunney?

Mr. TUNNEY. I have a couple of questions, Mr. Chairman.

What is the cost comparison between using atomic energy versus conventional sources of energy in desalting of water?

Mr. RAMEY. Well, Mr. Tunney, in the similar sizes it appears that conventional fuel resources will be cheaper than atomic energy. And that would be oil- or coal-fired boilers—using a distillation process.

As the plants get larger, nuclear energy begins to become cheaper, and it depends to a certain extent on the cost of money and other factors, exactly what size it is.

Our studies indicate that it would be at around between, I would say, 100,000 to 150,000 electrical kilowatts in size and upward. Of in terms of heat, it would be, say, 600,000 to 800,000 thermal kilowatts.

At 1,500 thermal megawatts, nuclear energy shows a clear superiority in terms of cost.

Mr. TUNNEY. How much water would that convert per day, using gallons per day, when it became cheaper to use atomic energy rather than conventional sources?

Mr. RAMEY. Again, the combination of a plant, for example the plant that is being studied, the type of plant being studied for Israel—the amount of water would be from 75 million gallons of water a day to 150 million gallons of water a day, and the amount of electricity would be, as I indicated, some 150,000 kilowatts to 200,000 electrical kilowatts.

Mr. TUNNEY. Are there any other feasibility studies forecast besides the two that I believe that you now have—one, the Metropolitan Water District in southern California, and then there is another which I cannot think of right offhand.

Mr. RAMEY. The Israel one. Those are specific engineering studies in depth, you might say.

As to others, we are in process of developing a study with Mexico, which would be under the International Atomic Energy Agency's auspices. Again, these overall studies, of course—this Office of Science and Technology study I referred to, does look at various sizes. It was our first real study in great depth.

And then more recently we did what we called our intermediate study, which was carried on by the Catalytic Construction Co. It covered sizes which would be from about 50,000 electrical kilowatts to 500,000 electrical kilowatts—from 200 megawatts thermal to 1,500 megawatts thermal.

We thought that plants of that size would perhaps be of greater interest abroad than these huge plants that we think would be more appropriate for what you might call regional water supply systems, say in our southwest.

We also participated with the Interior Department in a study of Key West, which was another specific site. The size of that study was about 50,000 electrical kilowatts, and about 10 million gallons of water a day. And that plant was found to be just marginally competitive with fossil fuel costs at fairly high price—that is around 40 cents per million B.t.u. for oil.

Mr. TUNNEY. Has this committee authorized any of the funds you used for your participation in these feasibility studies—the Atomic Energy Commission participation?

Mr. RAMEY. No, sir; you do not.

Mr. TUNNEY. What is the share of the cost, for instance, that the Atomic Energy Commission would have to participate in the study that is being done for the Metropolitan Water District out in California?

Mr. RAMEY. There it is being share on a tripartite basis, as I recall, with the AEC paying a third, the Interior Department paying a third, and the Metropolitan Water District paying a third—\$150,000 apiece.

And in the study, the Interior Department has acted as the Federal Government's contracting officer, and the Metropolitan Water District actually is the prime contractor for carrying on the study. They deal directly with the Bechtel people, who are undertaking the engineering study. And we have a technical man that follows it, and Interior has a couple of technical people that follow it.

Mr. ROGERS of Texas. Mr. Burton?

Mr. BURTON of Utah. Mr. Ramey, do you know the capacity of the fossil fuel plant at Point Loma?

Mr. RAMEY. The one that was there?

Mr. BURTON of Utah. That was there, yes.

Mr. RAMEY. Well, it was, I believe, a single purpose plant that made steam, and it produced initially a million gallons of water a day, and then it moved up to 1,400,000 gallons per day.

Mr. BURTON of Utah. One million. And this plant that you are projecting into 1975 would produce 300 million gallons—would be about 300 times the capacity of that plant at Point Loma?

Mr. RAMEY. Yes, sir, that is correct.

Mr. BURTON of Utah. I am merely a layman. I understand most of what your statement said, except I didn't understand what flash sea water is. You mention at page 2 a multistage flash sea water.

Mr. RAMEY. Well, I am not, and I don't profess to be an expert on the desalting side, but I have participated with the Interior people in this work. As I understand it, that means under more or less vacuum conditions, the steam flashes as a result of the way the process works.

Mr. BURTON of Utah. I am not sure I understand yet.

Mr. Ramey, we had this morning read into the record a letter by the chairman of the full committee from a Mr. Abel Wolman, who is a consulting engineer in Baltimore, Md. I would like your comment on two things.

In the third item in his letter Mr. Wolman says, "The simple multiplication of desalting units does not shed major light on the basic principles underlying the process. Hence building larger and larger capacity plants essentially composed of similar multiple units may provide diminishing returns."

Mr. RAMEY. Well, Dr. Wolman is a very qualified gentleman—I know him personally. He is an expert in the field of water and water research, pollution, and that sort of thing. He has also been a safety expert in the atomic energy field.

I think—and I would differ with him a little bit on the basis of the history of the nuclear game, of where we have gone from relatively small units, and by the scaling up, the engineering process of building larger units, we have been able to effect very great economies in terms of the cost and the technical simplicity of what we are doing.

For example, on pressure vessels—when the Shippingport reactor was built and operated back in 1957—that was only 8 years ago—Admiral Rickover built this as the largest prototype that could be built, and it was for 60,000 electrical kilowatts.

Mr. BURTON of Utah. What was this?

Mr. RAMEY. The Shippingport project, which is operating outside of the city of Pittsburgh, about 20 miles from Pittsburgh. This is a nuclear powerplant that makes electricity.

Now, that the Federal Government built the reactor, and the Duquesne Power Co. built the power conversion equipment.

But the largest pressure vessel that could be built then was about large enough to make 60,000 electrical kilowatts.

Well, 8 years later now they are contracting on a firm-price basis for pressure vessels for atomic powerplants that will produce between 700,000 and 800,000 electrical kilowatts. That is the scaleup of more than 10.

Mr. BURTON of Utah. What is the economic impact of scaling this up? In terms of cost.

Mr. RAMEY. Yes, sir. If you take Shippingport—Shippingport was our first industrial prototype. They estimated that the cost of power from this reactor—and this was not constructed for the purpose of making economic power—it was highly instrumented. But it was to learn an idea of the technical feasibility and the economics of future plants and fuel elements.

Well, they figured that the cost of power from that plant was around 60 mills, 6 cents a kilowatt-hour. The estimated cost of power from these plants that are being contracted for now, between 500,000 kilowatts, and the latest one, 800,000 kilowatts, is around 4 mills. So, again, the scaledown in cost is more than a factor of 10.

Mr. BURTON of Utah. The multiplication of the units upward has brought the cost downward?

Mr. RAMEY. It is the size.

Again, I don't profess to be an expert on the desalting side, and you would want to ask this same type of question to Mr. Di Luzio. We don't think there are as many complicating factors in the desalting side as there have been perhaps on the nuclear side.

But, on the other hand, there are some factors which are analogous. For example, on the side of modules, what they have been talking about is having—instead of having a module of a million gallons a day size, or 6 million which was what they were talking about perhaps a year or two ago, they talk now that the module might be 25 million gallons a day or 50. So that when you would be building a plant of 150 million gallons a day capacity, it might be composed of three 50-million-gallon-a-day modules. So that perhaps on increasing size of your plants, you do get some economies in constructing your building blocks somewhat larger.

As I understand it, also, just as in the nuclear game, you can standardize, and you can get thereby cheaper components and parts—we get cheaper fuel elements by building more of them.

Similarly, in the tubing and piping on the desalting side, when you build more of them, the unit costs of your heat surface would be more likely to go down.

Now, I don't think, from the studies we have made, that the cost would go down perhaps as fast as it has on nuclear, as a result of the scaleup. But I think this factor would have some effect.

Mr. BURTON of Utah. Thank you, Mr. Ramey.

No further questions.

Mr. ROGERS of Texas. Mr. Aspinall?

Mr. ASPINALL. No questions.

Mr. ROGERS of Texas. Mr. Wyatt?

Mr. WYATT. Mr. Ramey, has there been any one event or occurrence here in the last few months which suddenly now makes it feasible to spend as much per year on the general desalting program as has been spent over the entire 14 years immediately past?

Mr. RAMEY. Well, I don't think it is any one event. I think the program that the President approved, if implemented and put into effect, would mean going first into developing additional hardware on the desalting side in terms of module development, and the additional hardware work of this nature would mean an increasing curve on expenditures.

Similarly, on the nuclear side, once we get into actually coupling a nuclear reactor to a desalting plant, this will mean greater expenditures for the Commission on the development and the design and ultimately the hardware for them.

Mr. WYATT. Well, as far as you know, then, there has been no sudden technological breakthrough or development in the last year, say, that makes it more feasible now to leap ahead than it was, say, a year ago?

Mr. RAMEY. No, sir. This is an engineering development program. The events that occurred before last year, I think, that make this program make sense is, one, as I mentioned in my statement, that nuclear energy in the larger size reactors is getting cheaper, and that you have a source of low-cost steam in dual-purpose plants that makes it look more feasible to get water at a cost that would be perhaps economic for domestic, industrial, and municipal purposes.

The other thing that has happened has been that the Point Loma desalting plant operated successfully. It did demonstrate that you could make water somewhat cheaper than it had been before. The engineers who made—who have studied this experience believe that this technology can be scaled up to couple with nuclear reactors and come up with plants that would be producing water in the cost range I mentioned.

Mr. WYATT. In connection with your statement, the portion of it devoted to the international program, are you familiar in any detail with the type of information which we have given to other nations and which we have received from other nations?

Mr. RAMEY. Yes, sir; I am.

Mr. WYATT. Do you feel that our technology is further advanced than other nations in this field?

Mr. RAMEY. I believe our nuclear technology is better advanced than other nations. The U.S. Atomic Energy Commission and other countries participated in the Geneva Conference last September, in which there were survey papers and technical papers given on the status of nuclear technology. I think the general consensus was that the United States is still ahead.

There are other countries that are very well advanced—the United Kingdom, France, the Soviet Union, and Germany is coming up fast. That is on the nuclear side.

On the desalting side, I believe—and, again, you would want to ask Mr. Di Luzzio on this—certainly the British have done quite a bit of work on desalting plants, small scale plants that have been built in such places as Kuwait and other places such as the Caribbean.

I would think in terms of an organized program, we are a little bit ahead of them. And I think we have had a little more success in our development program, from the meetings that I have participated in. The Soviet Union also has built a plant that Secretary Udall mentioned this morning, on the Caspian Sea.

Mr. WYATT. What about the United Arab Republic, and the reviewing of their needs and their potential for nuclear desalting? Has this resulted in our giving technical information to the United Arab Republic?

Mr. RAMEY. The United Arab Republic has participated in these panels conducted by the International Atomic Energy Agency, and

at those panels, each participant, including the United States, gives papers. And so there has been—they have received our papers, which are, of course, unclassified, and we have received their papers.

In addition, at the last meeting they talked to the U.S. Government, to the Interior people, and to myself, about looking into their needs. And so we sent a team over there last fall who visited the United Arab Republic and Tunisia, to assess whether a nuclear desalting plant would be feasible in terms of their requirements.

During that period, they had gone out for bids to American reactor manufacturers and desalting equipment suppliers, as well as to British, French, and other countries, and asked for proposals on a plant that would produce, as I recall, around 100,000 to 200,000 electrical kilowatts, and about 5 million gallons of water a day. The water would be used there in an experimental irrigation area along the Mediterranean, and the power would go into their grid.

Our people went over there on a team effort with the United Arab Republic, and our report is not out yet—it ought to be out in the next month or two.

Mr. WYATT. Approximately how many of our people went to the United Arab Republic for approximately how long?

Mr. RAMEY. There were three people—one AEC engineer, two from the Department of Interior, one from the Bureau of Reclamation, as I recall, and one from the OSW. And they were there approximately a week to 10 days. We have followed a similar type of approach with Israel. We would plan to do this when we initially look at the Mexico situation.

We find this is a rather convenient way of getting a sort of first cut on whether or not it makes any sense to look at the matter any deeper.

Mr. WYATT. Are there any plans, either tentative or underway now, to build any technical facilities in the United Arab Republic?

Mr. RAMEY. No.

Mr. WYATT. Those are all the questions I have.

Mr. ROGERS of Texas. Mr. Reinecke?

Mr. REINECKE. Thank you.

You referred to the price of power at 4 to 6 mills per kilowatt-hour. What amortization life is this, referring to the equipment?

Mr. RAMEY. This would be using private utility financing and amortization, and it would be a 30-year amortization period, and using normally a 12- to 14-percent fixed charge override on their costs.

Mr. REINECKE. These investment costs are reflected in this 4- to 6-mill figure?

Mr. RAMEY. Yes, sir.

Mr. REINECKE. On the combination powerplants—maybe I don't have the concept quite clearly—any time we take power out of a given system for use such as in a desalting process, are we not thereby lowering the efficiency of what the plant was originally intended to put out if it was basically an electrical generation plant? We have only got so much energy, and we have got to split it and go two ways, so we really are not getting something for nothing here, are we?

Mr. RAMEY. I don't think we are getting something for nothing. And you appreciate I am not an engineer by training. I have Mr. Williams here.

From my lay understanding of it, it is that in your turbine generator system, it is economical to take your high pressures, higher temperature steam through a part of your turbine generator, and then it is your lower temperature or lower pressure steam that you could bleed into a desalting system, and thereby get a more efficient use of the heat coming from a reactor. Reactor heat is relatively low temperature, low pressure steam, anyhow.

Also, the actual steam that finally comes out from a generator, from a nuclear power electric generator, would then be routed, instead of going to the condenser, would go through the desalting facility.

Now, you are not getting something for nothing, but you do get some advantage. You don't get as much actually as people might think, my technical people tell me.

Mr. Williams, do you want to comment on that?

Mr. WILLIAMS. As an example, let us assume that you have a given thermal size for your heat source, say a reactor of 1,500 megawatts thermal capacity. If used in a power only situation, you would expect somewhere in the neighborhood of about 500 megawatts of electricity to be produced, 500,000 electrical kilowatts. If you use this same reactor in a dual-purpose application, the electrical production would be reduced perhaps to the neighborhood of about 200 megawatts electrical, but you could provide the energy necessary to produce approximately 150 million gallons of water a day.

Mr. REINECKE. But basically we still are not getting something for nothing. That steam you are applying to the salt water could also be applied to the intake water, to preheat that before it goes into the boiler.

Mr. RAMEY. Yes.

You do get the advantage of building a larger plant than you would build for power or for water only, and by building a larger plant your unit costs of steam go down, for both purposes. That is one of the economies.

Mr. REINECKE. Thank you.

Just for my information—maybe everyone else understands it—but I would like a clarification or solidification of the difference between thermal kilowatts and electrical kilowatts.

Mr. RAMEY. Well, the thermal kilowatts are your kilowatts of heat of the steam, and the electrical kilowatts are what comes out of your electric generator normally. And this is a sort of a measure, I guess, of the efficiency of your system.

Normally, you divide your thermal megawatts by 4 to come up—sometimes 3—to come up with your electrical kilowatts, in a nuclear powerplant.

Mr. REINECKE. Instead of referring to it as so many B.t.u. of energy, you talk about thermal kilowatts?

Mr. RAMEY. Yes, sir.

Mr. REINECKE. Do you feel we are at a stage in this whole technology where we are really ready to go ahead and build large-scale plants, using nuclear sources, or do you feel that there is a good bit of research and development and technology yet to be accomplished before we can spend large amounts of money on full-scale plants?

Mr. RAMEY. Well, it depends on how you define large-scale plants.

We think that there are these commercial nuclear heat sources that can be coupled, with some engineering and design effort, with desalting plants in the sizes of 50 to 150 million gallons a day.

Now, these desalting plants, in terms of what are in existence today, would be large, but in terms of future projections on very large sizes—they are what we would call intermediate size plants.

We think with some engineering development on the coupling of reactors to desalting plants, that this could be accomplished in the next few years. And this is what we are working on now, these engineering studies on what is the most optimum way, the optimum amount of power as against water in the systems—how you design them to get the most efficient use of your power facility and the desalting facility, and so on.

Mr. REINECKE. Would you recommend final completion of these studies prior to the construction?

Mr. RAMEY. Yes; we would not want to start actual construction of plants until we have had finished these types of design studies.

Mr. REINECKE. Thank you very much. No further questions.

Mr. ROGERS of Texas. Mr. Aspinall.

Mr. ASPINALL. Thank you, Mr. Chairman. I am sorry I was not here to hear the Commissioner's presentation. He always makes a very effective and factual presentation.

Mr. RAMEY. Thank your, sir.

Mr. ASPINALL. Mr. Commissioner, how much did the Atomic Energy Commission spend on desalting programs in this field during fiscal 1965?

Mr. RAMEY. That would be through this June 30th?

Mr. ASPINALL. That is right.

Mr. RAMEY. It would be around \$1 million.

Mr. ASPINALL. And how much is proposed in the next fiscal year?

Mr. RAMEY. It is budgeted at around \$2.9 million.

Mr. ASPINALL. What do you propose, then, for the 5-year life of the extension period as set forth in the legislation now before us?

Mr. RAMEY. That amount of money would go up modestly. That portion which is directly applicable to desalting would be about \$20 million for the 5-year period. This would be in addition to our other reactor development efforts and prototype assistance such as the heavy water organic-cooled reactor program.

Mr. ASPINALL. That would be in addition to the \$200 million which is being requested in this legislation; is that right?

Mr. RAMEY. Yes.

Mr. ASPINALL. Now, you have kept in close touch with the Department of the Interior. Do you have your program envisioned for the additional period proposed to be authorized by this legislation? In other words, do you have your goals set up?

Mr. RAMEY. For the period beyond the 5 years, or for this 5-year period? Yes, sir.

Mr. ASPINALL. You have that.

Is that in such form that you can give it to the committee?

Mr. RAMEY. Yes, sir.

Essentially, the general scope and goals are set out in this report to the President, I would say, Mr. Aspinall. We could—I would be glad to specify it in greater detail, if you felt that was desirable.

Mr. ASPINALL. I understand we have never even received the report. And we would like to have something in this respect in the record of the hearing.

Mr. RAMEY. We brought——

Mr. ASPINALL. Are you in position to give us a copy of the report?

Mr. RAMEY. Yes, sir; we brought 50 copies to the session this afternoon, after the question that was raised in this morning's session.

Mr. ASPINALL. We have the Interior report.

Mr. RAMEY. Yes, sir. We brought copies of the joint report.

Mr. ASPINALL. Mr. Commissioner, where is the joint report?

Mr. WILLIAMS. Mr. Aspinall, the joint one is the report that states at the bottom: "In collaboration with the Atomic Energy Commission." Starting about two-thirds of the way through the report is the portion that pertains to the Atomic Energy Commission.

Mr. RAMEY. We submitted a report with the Interior Department. I think the confusion arose was that the Interior Department, for uses in their own Department, had just put out the Office of Saline Water part of the program, and they used the same cover with the Atomic Energy Commission heading left off.

Mr. ASPINALL. Well, Mr. Chairman, I don't believe we should put it in the record. I would ask this report to the President, entitled "Collaboration With the Atomic Energy Commission," be made a part of the files, so we don't lose it.

Mr. ROGERS of Texas. Without objection, it will be made a part of the files.

Mr. REINECKE. Will the gentleman yield?

Perhaps this should be off the record. But there must be a third report, because this is not the other one that I saw. The other paper which I saw had some bar graphs in it that I was interested in, which are not in either of the two I have now.

Mr. WILLIAMS. This contains the only report that the AEC has published, sir.

Mr. RAMEY. There have been reports on these engineering studies that I mentioned, that carry various graphs and bars and so on.

Mr. REINECKE. As a matter of fact, the other cover, Mr. Chairman, is brown instead of black—it is the same cover, but it is again another report. Apparently Mr. Di Luzio knows something about it.

Mr. ROGERS of Texas. It is this one?

Mr. REINECKE. No; it is the same printed copy, but it is either a beige paper or brown ink. It is something different. Just a few pages.

Mr. ASPINALL. Mr. Commissioner, as we are thinking about this period—into the seventies—we talk about 150-million-gallon-per-day plant, and a 300-million-gallon-per-day plant, what do you envision as of this time, or have you thought about it, as to what the cost of the water will be at that time?

Mr. RAMEY. The estimate of the cost of water from these plants that would produce, say, from 75 to 150 million gallons of water a day, and using the current reactor technology, which is to say we would also produce perhaps 200,000 or 300,000 electrical kilowatts—the projected cost of water is in the range of 30 cents a thousand gallons—anywhere from 28 to 33 cents, in that range.

Mr. ASPINALL. Which means a hundred dollars per acre-foot.

Mr. RAMEY. Roughly: yes, sir.

Mr. ASPINALL. When you talk about a 300-million-gallon-a-day operation, you are talking about a 900-acre-foot-per-day operation. And if you carried that out into the period of a year, you are talking about 340,000 acre-feet of water, which might be a sizable supply as far as the amount is concerned for irrigation. But do you think that there is any possibility of making water available for irrigation under the program that is presently envisioned?

Mr. RAMEY. Not in the period of the 1970's, Mr. Aspinall. The costs of water during this period would be much in excess of the price of irrigation water.

I think the idea of this program, of going to these sizes is going to get the technical and economic data to project what these desalting plants could do in the 1980's in very large sizes.

Mr. ASPINALL. Now, let your engineers and scientists answer this question. How much do they figure they can break this down by 1990?

Mr. RAMEY. Well, my understanding is—of course, that is a good ways away.

Mr. ASPINALL. I know it. But we have before this committee the southwest water plan, which is being talked about as including a desalination as a possible means of supplementing the water supplies of the Southwest. I just want to know what we are talking about.

Mr. RAMEY. These estimates for the larger plants in the 1970's—the cost of water gets down to around 20 cents a thousand gallons, and then these very rough estimates for plants beyond that, they think, taking the economics of size again, would be that you would get below a 20-cent figure.

Now, we have not felt that we are in a position to really be saying how much below we would be getting.

Mr. ASPINALL. Well, I take it that is your best figure, and that will be some place between 10 cents and 20 cents per thousand gallons, and I will take the lower part of that, and still your water is going to cost some place between \$30 to \$45 per acre-foot.

Mr. RAMEY. Yes, sir.

Mr. ASPINALL. You cannot even use that kind of water for irrigation, and you cannot keep saying to the people of the United States that we are going to use desalted water for irrigation, because we can transfer it hundreds of miles perhaps cheaper than even your lowest cost.

Mr. RAMEY. You appreciate, Mr. Aspinall, that in our statements we have not claimed that the technology, as we have developed it, and how we project it, will achieve what is being charged, what the prices are for irrigation.

We have thrown out the hope—and, again, this may be overly optimistic. But we have the experience in the atomic power field where we are in process of achieving economic atomic power somewhat ahead of the time anyone thought we would be able to do so. And we have been pretty successful in the nuclear power applications.

Now, what we are trying to do on the technology, on these combination plants, is to see whether or not, by the engineering improvement and development of these plants, that water in the very large amounts would be at least competitive with other sources in the 1980-90 period.

Now, one of the things that we will be doing in the next 10 years, of course, is getting a better figure on what the comparative costs of

other sources of water are. We will be in a situation, then, by the time our prototypes are in operation, to have a pretty good idea of what it costs on the dual-purpose nuclear desalting side in the bigger plants, and what it would cost in bringing water down from other places. And it could be that the nuclear desalting plants would be competitive.

I know you know much more about this than I, as to the differences between the cost of producing water and the price of water—that there are these differences, the same as in the electric energy game.

Mr. ASPINALL. Of course the only place this water can be possibly used would be in some large cities, as far as the seventies are concerned, where it might be needed, so that they would use it for municipal water at this price.

Mr. RAMEY. Yes, sir—and for industrial purposes, perhaps.

Mr. ASPINALL. For certain industrial purposes. That is pretty expensive water for industrial purposes, when you can circulate polluted water in many of your industrial operations.

I think that is all.

Mr. ROGERS of Texas. Did you have a question, Mr. Burton?

Mr. BURTON of Utah. Mr. Chairman, I just want to underscore what the gentleman from Colorado had said. In using this \$30 to \$45 an acre-foot cost, the gentleman is giving the program practically every conceivable benefit of the doubt, and that is almost an unrealistic figure.

Mr. ASPINALL. As you might water pansies in your window, but that is about as close as you are going to get.

Mr. ROGERS of Texas. Mr. Commissioner, in discussing further this cost—now, we talk about a dual-purpose project or plant. Now, do I understand that the same energy cost is being applied against the desalting water process as is being charged against the production of electric energy?

Mr. RAMEY. Well, essentially, yes. The method that we have used to set a power value as to the value of the steam for electric power purposes is the cost of the cheapest alternate source of energy in a single-purpose installation. And then figure out the cost of water from there in the dual-purpose installation using that as the value of the power.

Mr. ROGERS of Texas. Well, now, we have heard a lot of discussion in Congress about waste power, power in a nuclear plant that would be wasted if it was not used for, we will say, production of electric energy, and I presume the same could be applied to desalting water.

Now, we are talking here about a plant designed to produce electric energy, and also to make it possible to desalt water.

Mr. RAMEY. Yes, sir.

Mr. ROGERS of Texas. What I am thinking about is just how far we are going in the question of waste energy. Are we making the determination on 10- or 20-cent water from the premise that this energy is going to cost less because it would be wasted if we didn't use it?

Mr. RAMEY. No, sir; it is not. It is an accounting method that does attribute a cost to the steam that goes into the desalting plant. And that cost essentially is the difference between the total cost of the steam and the cost that is attributed to the electric power production, which is the cost of the cheapest alternate source.

Mr. ROGERS of Texas. How much cheaper is that when applied to the desalting process than would be the cost if the steam was made for the simple purpose of desalting water?

Mr. RAMEY. Well, the main advantage that you get from this dual-purpose application, Mr. Chairman, I guess, is that you are building a bigger plant, and, therefore, the unit cost of the steam is cheaper for either purpose than it would be if you built a plant just for electric power production.

In other words, if you built a smaller plant for making electric power, your costs would be a little higher than if you built a bigger plant.

Mr. ROGERS of Texas. Now, as I understand it, you do contemplate building nuclear powerplants for the production of electric energy.

Mr. RAMEY. Yes, sir.

Mr. ROGERS of Texas. I mean the Atomic Energy Commission is going to do this, regardless of what happens to desalting.

Mr. RAMEY. Yes. The private and publicly owned utilities are building them now economically.

Mr. ROGERS of Texas. Yes; I understand that.

In other words, the production of electric energy can be found from nuclear energy as a source.

Mr. RAMEY. Yes, sir.

Mr. ROGERS of Texas. Now, the next thing is, as I understand you, when you translate thermal kilowatts into electric kilowatts, you lose about 3 of your thermal kilowatts to produce 1 electric kilowatt.

Mr. RAMEY. Yes, sir.

Mr. ROGERS of Texas. Now, what happens to those 3 thermal kilowatts? Are they lost altogether in an electric plant, or are you utilizing them for the desalting process?

Mr. RAMEY. Well, perhaps Mr. Williams can explain that again.

My understanding is that we do re-use some of the steam that comes from the electric generator, the steam that would ordinarily go to the condenser, and then back into the reactor or boiler. So there you do get the advantage of this aspect of it in your cycle.

In addition, when you are designing a dual-purpose plant, you steal a little of the steam that would normally go through your generator and bypass it into your desalting plant, also.

Now, for both of these types of steam, we are giving a certain cost and a certain value. In other words, the desalting plant doesn't get this for nothing.

Mr. ROGERS of Texas. Yes; I understand that.

Now, if you didn't have that desalting plant on there, what would happen to this steam, would it just be wasted?

Mr. RAMEY. Well, it would go—the steam—you would build your generator a little differently to take as much advantage of your heat as you could, and then the steam that does go through your turbine generator then would go to the condenser and back. And in that sense it is wasted.

But I think there is a nice scientific point that the engineers and scientists make, that from a thermodynamic standpoint you are not really taking waste heat and utilizing it in your desalting facility, technically speaking.

Is that right?

Mr. ROGERS of Texas. Would you like to address yourself to that?

Mr. WILLIAMS. Yes, sir, Mr. Chairman.

Actually, in a power-only-type installation, you take water and apply energy to it, and you cause steam to be formed, usually at fairly high temperatures and pressures. This is led to a turbine, and generally speaking the higher the temperature and the higher the pressure the more valuable that steam is for power generation—it is more readily usable. As you get to the lower pressures, as you go through a turbine, it becomes less and less valuable.

Normally speaking, it would be rejected to a condenser at roughly 90° to 100° , under a vacuum condition—where you strip as much of the energy out as economically practical. This would give you an overall plant efficiency, perhaps, in the neighborhood of 33 to maybe even 40 percent, depending on the original temperature. And the dual-purpose concept—you still have the water, the applied energy, causing it to form into steam, and you take it through a turbine, only to the extent that it is really valuable for power, and you take, not waste steam, but exhaust steam at something above this 90° , say it is 200° , and you lead this to a desalting plant. And this furnishes energy there.

In the power only case, when you exhaust this steam to a condenser, you lose the heat of condensation. We can take advantage of that heat of condensation by running it to a desalting plant, say the brine heater, and then return it to the reactor. So there is an advantage to coupling the two plants together from a thermodynamic standpoint.

Mr. ROGERS of Texas. How much is your efficiency reduced by making a dual-purpose plant rather than a single purpose?

Mr. WILLIAMS. Usually the efficiency is given on the conversion process in a power only type installation.

From a thermal standpoint, I would say that you probably have an increased efficiency in the use of the energy by perhaps as much as 25 percent, sir.

Mr. ROGERS of Texas. In the use of the energy?

Mr. RAMEY. In the overall.

Mr. ROGERS of Texas. Which means the production of electric power, plus the desalting process.

Mr. WILLIAMS. Yes, sir.

Mr. ROGERS of Texas. What I have reference to is how much is your efficiency reduced when you relate it only to the production of electric energy?

Mr. WILLIAMS. I think you could say maybe there is a loss of perhaps 10 to 25 percent in the power only case.

Mr. ROGERS of Texas. But the one thing that is in the back of my mind is the cost of energy used—there is a base cost for your energy, for the desalting process, so that we don't run into the proposition later on of this being called, let's say, a subsidy, saying that the Pacific southwest is getting a huge subsidy, because this energy that would be used otherwise is being used to desalt water that is being made available to those people there—therefore, people in the other part of the United States are entitled to the same type of subsidy, to produce water or to reduce pollution.

Mr. WILLIAMS. I think you can assign a value to the cost of prime steam—this is your high-temperature, high-energy steam.

I think you can also derive from its use in a turbine, depending on the takeoff point, an equivalent value for the exhaust steam to be used in a desalting plant.

Mr. ROGERS. Would you think that the desalting along with a production of electric energy is probably the best dual purpose project, or would there be some other purpose that you could associate with the production of electric energy that would pay greater dividends than desalting water, or trying to desalt, rather?

Mr. RAMEY. We looked at the application of process steam and electricity in paper mills, and that sort of purpose; and we found there—and this was in the late 1950's—that the size factor hurt us. This would be maybe making 25,000 electrical kilowatts, and an equal amount of steam for use in a paper or chemical plant. We found that that was just marginally economic. And we didn't find many people interested in doing it.

One of the reasons we found was that plants like this use wood, scraps, and various other types of waste material as their heat source.

Mr. ROGERS. Then we can conclude that the dual purpose would be best served by the desalinization process along with the production of electrical energy?

Mr. RAMEY. I would say so. It is particularly adapted at the present time to these types of nuclear reactors that do not make high temperature steam, so that the steam coming out of the turbine goes through the normal drop, and then it is not so far off from what would be needed for a desalting plant anyhow.

Mr. ROGERS. Is research continuing on this particular type of problem?

Mr. RAMEY. Yes. One of the reasons we are doing this now is to get an idea of the optimum use of the heat energy for power and water; because this ratio of your power to your water differs as to the temperature of the reactor. When you have a higher temperature reactor you would be producing a higher ratio, a higher proportion of steam, and you would normally be producing more electric power proportionately to your water; whereas if you were using a water type reactor you would be producing a higher ratio a higher proportion of water to your electric power production. The cost of water in each case would be about the same.

So you can vary these, depending on the particular needs of the area. If the area is deficient in electric power, then you might build one kind of reactor, or fossil-fired plant. If it is deficient and needs larger quantities of water, then you would design it to get the optimum amount of water.

So one of the things that we always advocate is that you can't really talk about these matters in the abstract entirely, you have to take a particular area and see what the particular needs of that particular area are in relation to power and water.

Mr. ROGERS. And that would have to do with dual purpose?

Mr. RAMEY. Yes, sir.

Mr. ROGERS. With whatever other purpose outside of electric energy would best be served or would best serve in that general area?

Mr. RAMEY. Yes, although again in these sizes—of course, you might be able to use the steam for something else, for heating, perhaps.

Mr. ROGERS. Mr. Reinecke.

Mr. REINECKE. I would like to ask Mr. Ramey if we can't look at it by saying that the steam used for desalting is actually an alternate use or a management decision to take the steam part way through its expansion and use it for another purpose. And in its combination it is conceivable from an engineering point of view to get a slight increase, on the order of 10 percent. But doesn't this also tie us to optimum conditions of performance and such that if we ever need more power, as the combination was originally set up, we may find ourselves operating less efficiently unless we always operate at that peak point of efficiency?

Mr. RAMEY. That is one of the things we are doing engineering studies on, to see whether or not you could build turbines and generators, and tie them to desalting facilities and reactors, so that you could get some flexibility, depending on changing conditions. This is one of the areas that our engineering research and development is being directed toward.

Mr. REINECKE. The point being that conceivably 10 or 15 years after the plant is built another source of electrical energy may come in that will be cheaper, and you may not want to produce that much electrical energy at the nuclear plant thereby operating the water plant at a higher cost.

Thank you.

Mr. ROGERS. Let me ask these other questions quickly. There is a rollcall on the motion to recommit, and we will have to go to the floor on that, but we will come right back as soon as the vote is over.

Did you anticipate any problems in locating a site for the combination nuclear power in the desalting plant?

Mr. RAMEY. We don't anticipate any greater problems in site selection for dual-purpose plants than there are for single-purpose nuclear plants. We do have somewhat stringent safety factors to take into account in the selection of sites. Normally ocean sites or water sites are preferred for nuclear electric power production anyhow, because: one, it gives a certain amount of an area where there is no population; secondly, it provides you with cooling water for your powerplant anyhow.

Mr. ROGERS. But you feel that there are plenty of locations for that?

Mr. RAMEY. Well, I wouldn't say there are plenty. Particularly on the west coast, the siting of reactors and powerplants of all types is something of a problem. This is one of the things, for example, that they have been giving a lot of attention to in his metropolitan water district study. They have been looking at various alternative sites.

Mr. ROGERS. Mr. Commissioner, do you or does the Atomic Energy Commission feel that it needs the authorization contained in the act pending before us in order to continue research on combination plants or dual-purpose plants?

Mr. RAMEY. Well, since we are working in tandem with the Interior Department here, and we have plans that are pretty well coordinated, we think that it is essential for the Interior Department, if this program is to continue going along, to get the authorization. Our activities at this time are in the engineering and development stage, so that we don't have quite the urgency to go to module development and hardware development that the Interior Department does in terms of scaling up their desalting technology.

Mr. ROGERS. Now, there is a report going around that there is some thought of building an island off the coast of California. Is there any substance to that, Mr. Commissioner?

Mr. RAMEY. I think in these various studies going on, the question of locating atomic reactors and dual-purpose plants, not just on the shore, or just back of the shore, but out by breakwaters and perhaps on man-made islands, have been considered. For example, we considered this in our Key West study.

Mr. ROGERS. A man-made island?

Mr. RAMEY. Yes, sir.

Mr. ROGERS. What do you anticipate is the cost of such a project as that, either on the west coast or on the southwest coast?

Mr. RAMEY. I just don't know, Mr. Chairman. Again the cost is a relative thing. Land values are extremely expensive on the west coast now and in Florida for that matter. So I am sure the metropolitan water district or anyone else wouldn't go to this approach unless it did have cost advantages over other alternatives. And also it has certain safety aspects, too.

Mr. ROGERS. Is that under consideration now by the Atomic Energy Commission? Are you all doing any research on that type of an operation?

Mr. RAMEY. I believe the contractor, the engineering contractor in this MWD study has looked at this as one alternative among a number of different alternatives.

Mr. ROGERS. He hasn't submitted anything firm insofar as completing such an island?

Mr. RAMEY. No, sir. But I think probably when their report is submitted this fall we will get the results of whatever look they have taken at this alternative.

Mr. ROGERS. We would like to know what their proposed cost might be. We wouldn't want to use the whole \$200 million with it.

Thank you very much, Mr. Commissioner, and Mr. Williams. We will go over and answer the rollcall, and come back in 20 minutes.
(Recess.)

Mr. ROGERS. The Subcommittee on Irrigation and Reclamation will come to order for further consideration of the pending business.

Our next witness this afternoon is the Director of the Office of Saline Water, Mr. Frank C. Di Luzio.

Mr. Di Luzio, it is nice to have you before our subcommittee.

Will you introduce your aids so that the record will reflect it.

STATEMENT OF FRANK C. DI LUZIO, DIRECTOR, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY SHERMAN GILLAM, ASSISTANT DIRECTOR FOR RESEARCH; J. A. HUNTER, ASSISTANT DIRECTOR FOR ENGINEERING AND DEVELOPMENT; AND EVERETT N. SIEDER, ACTING CHIEF, DISTILLATION DIVISION

Mr. DI LUZIO. On my right I have Dr. Jack Hunter, who is Assistant Director for Engineering and Development, and on my left I have Dr. W. S. Gillam, Assistant Director for Research.

I would like to submit for the record at this time, statements by Dr. Hunter, Dr. Gillam, and the rest of the engineering staff. They do not propose to present them orally. I will try to pick up most of the major points which they have made.

Mr. ROGERS. Mr. Di Luzio, all those other statements that you have are of the different processes?

Mr. Di LUZIO. Yes.

Mr. ROGERS. Without objection the statements of the other gentlemen to whom you are referring will be included in the record after your statement and the questions and answers.

Mr. DiLUZIO. Thank you very much. Herewith is presented my prepared statement.

Mr. Chairman and members of the committee. I am pleased to have the opportunity to testify before you today in behalf of the legislative request of the President for an expanded and accelerated saline water conversion program. We will endeavor to fully describe the activities we propose to initiate, the reasons why we believe these steps are necessary and what we expect to accomplish.

When I assumed my responsibilities as Director of the Office of Saline Water, the scope and thrust of the water desalting program objectives were in a period of transition. I have made a rather exhaustive review of past activities in order to acquire a sound perspective of the status of the program relative to technical developments, and to determine in my own mind what are, or should be, the relations of the Office of Saline Water with other Government agencies, the scientific community, and the States; and more important, the role of the Office of Saline Water in relation to industry.

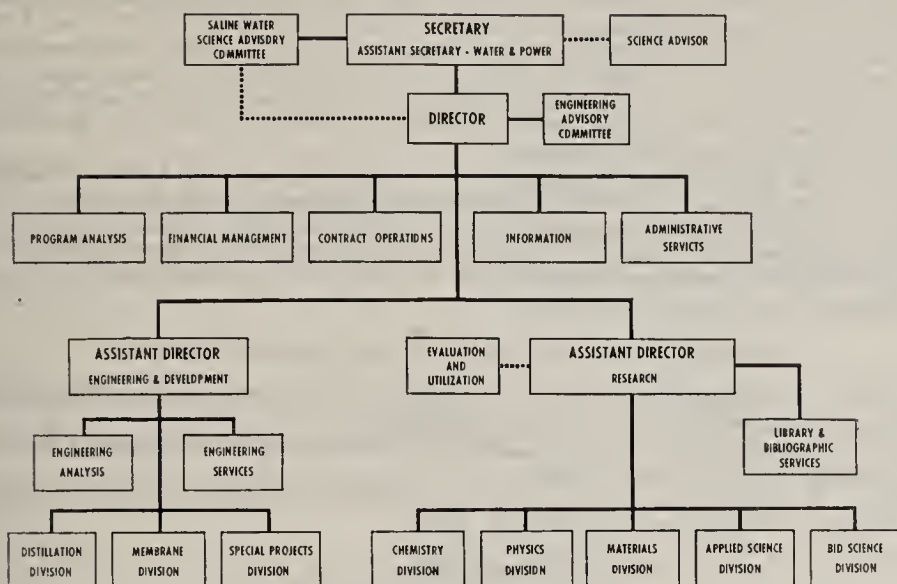
It has been interesting to note that other governments are increasing their desalting activities. Through our exchange of information with the U.S.S.R. last year, we found that the Soviet Government has a very extensive program underway. The Government of Israel is supporting an active program, as is the Government of Japan. On April 27, the Minister of Technology announced in the House of Commons that the United Kingdom will carry out research programs and design studies on desalting processes. The main emphasis of the desalting research and design program will initially be on the multistage flash distillation process, but the British program will also include work on other techniques. When one analyzes who the customers for plants will be, this action is no surprise. Government interest and activity is increasing in Spain, Italy, and to a lesser degree, Greece and Australia, and a number of other countries as well.

Perhaps the best bellweather we have of international interest is the response we have had thus far to the invitation we have extended to governments to attend the first international symposium on water desalination which will be held here in Washington this October. As of now, 53 nations have indicated they will send an official delegation to the meeting. Through the exchange of information at this symposium, we expect to have a clearer understanding of the work sponsored by other nations, and thus minimize duplication of effort.

We have received numerous contacts from governments for technical assistance, and we can expect these contacts to increase. All official requests for such assistance are coordinated with the Department of State. I think it can safely be stated that on a worldwide basis the Office of Saline Water has attained recognition as the intellectual leader in desalting technology and is considered the greatest repository of saline water conversion information. Hardly a day goes by that we do not receive several requests from overseas for desalting data and at least once or twice a week we receive visitors from outside the United States who are deeply interested in our program.

I have devoted much thought to the aggressive desalting program the President seeks and the steps that will be required to effectively reach meaningful goals. As a first step, the organization of the Office has been completely revised as shown on this chart.

(The information referred to follows :)



"EXPLANATION OF ORGANIZATION CHART, OFFICE OF SALINE WATER

"The level of effort which the expanded program envisions and the emphasis we will place on engineering and plant construction has carried with it the need to effectuate major revisions in the organization structure of the Office of Saline Water. We will also need additional personnel with experience and expertise to carry out the program mission with optimum efficiency.

"Up to this time, a major activity of the Office has been to stimulate interest and disseminate information, study the economic potential of available processes, and explore the possibility of developing new methods of desalination.

"The present state of the art has reached a point where the future thrust of the program must be recast, placing primary emphasis on engineering. This will enable us to develop the hardware needed to improve and implement the utilization of processes and components which merit further enlargement and improvement. The administration of a program which includes the engineering developments leading up to and including the construction of a 50-million-gallon-per-day plant will obviously require many diverse talents not previously needed by the Office.

"The former organization of OSW was a horizontal pattern consisting of three technical divisions; namely, the Division of Research, the Division of Processes Development, and the Division of Demonstration Plants. There was also a fourth division for Contracts and Administration which included everything from housekeeping services to auditing. All of these divisions reported directly to the Office of the Director.

"The new OSW organization is devised to provide a systems management approach to efficient program execution. The direct line of responsibility funnels from the Director through three principal areas of program responsibility and authority; namely, "Development and Engineering," "Research," and "Administrative Services." The development of processes has been divided into three operating divisions: Distillation, Membranes, and Special Projects (freezing, hydrates, and special components). Staff and administrative services have been segregated to conform more clearly to definite functional responsibilities. A Program Analysis Staff has been established to insure continuous competent review of the program to assist the Director in maintaining a proper balance of effort and coordination of programs. A refined water economics program will enable us to acquire competency in this highly complex area. Steps have already been taken to establish a highly competent outside engineering advisory group to augment internal engineering competency."

Some of the answers I have sought have been easy to come by; but others, especially some of the technical aspects of the program as they relate to current research and development activities on various conversion processes, are not yet apparent. To help obtain some of the additional information we will need, I have appointed a highly competent group to undertake a thorough and hardheaded engineering review of all processes by category. This type of study is underway on the freezing processes to ascertain their scientific merit, their economic potential, and their practical application. Similar reviews will soon be undertaken for all the other process categories.

When this information is compiled and analyzed, we will be better able to reorient our program to reduce or terminate development work on processes that do not warrant further support and to assign priorities to the development of those processes which appear to provide the greatest technical promise for cost breakthroughs. I am appending for the record a list of the distinguished people who will serve on this review group.

COMMITTEE FOR EVALUATION OF THE FREEZING PROCESS

- Dr. Allen J. Baduhn, Department of Chemical and Metallurgical Engineering, Syracuse University Research Institute, Syracuse, N.Y.
 Dr. P. L. T. Brian, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
 Prof. T. K. Sherwood, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

RESEARCH REVIEW BOARD

- Dr. K. S. Spiegler, Sea Water Conversion Laboratory, University of California, 1301 S. 46th Street, Richmond, Calif.
 Dr. Henry S. Frank, Mellon Institute, 4400 Fifth Avenue, Pittsburgh, Pa.
 Dr. Charles L. Thomas, Sun Oil Co., Marcus Hook, Pa.
 Prof. E. R. Gilliland, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
 Dean Ralph A. Morgen, Stevens Institute of Technology, Castle Point Station, Hoboken, N.J.

COMMITTEE FOR EVALUATION OF DISTILLATION PROCESSES

- Dr. Myron Tribus, Thayer School of Engineering, Dartmouth College, Hanover, N.H.
 Dr. B. F. Dodge, Department of Chemical Engineering, Yale University, New Haven, Conn.
 Mr. Ed H. LeBeis, Jr., 746 Pine Ridge Road, Media, Pa.
 Dr. A. E. Dukler, Department of Chemical Engineering, University of Houston, Houston, Tex.
 Mr. Paul Buckingham, the Fluor Corp., Ltd., 2500 S. Atlantic Boulevard, Los Angeles, Calif.

COMMITTEE FOR EVALUATION OF REVERSE OSMOSIS

- Dr. Ulrich Merten, General Atomic Division, General Dynamics Corp., Post Office Box 608, San Diego, Calif.
 Prof. J. W. McCutchan, Department of Engineering, University of California, Los Angeles, Calif.
 Dr. Alan S. Michaels, president, Amicon Corp., 280 Binney Street, Cambridge, Mass.
 Dr. B. Keilin, head, Chemical Resources Department, Aerojet-General Corp., Azusa, Calif.
 Dr. Kurt A. Kraus, Oak Ridge National Laboratory, Post Office Box "X", Oak Ridge, Tenn.

Our accelerated program objective will be to place greater emphasis on engineering problems and the development of hardware for prototype plants. In the conduct of a program of this magnitude and scope, we can predict that the leading engineering concepts which evolve, will need to be tested and proved out in prototype intermediate-size plants, or in modular fractions of plants, scaled for 50 million gallons per day or larger. Data presently available are too meager to enable us to forecast, at this time, the specific need for legislation to support

such activity. In this situation, the applied research and engineering development work leading to the preliminary engineering or scope designs of such such plants will be acquired and then decisions on the need for additional legislation can more clearly be identified. We would then come back to the Congress with a request for specific legislation which we would need to support large-scale prototype plant construction.

In analyzing the proper role of the Office of Saline Water to develop desalting technology and that which industry can most advantageously perform—and this analysis has been conducted through many lengthy discussions with industry representatives—one finds general agreement that the Office of Saline Water should bear the major responsibility of proving out a process. That is, to carry the development of technology to a point where it meets a specific need. This development work will be carried on by the Office of Saline Water in cooperation with industry. To reach this point of technical and economic development with some processes may only involve the construction of a first-generation plant, with other processes it may require the construction and field operation of several succeeding generations of plants.

Once the economics of a process have been brought into a practical range, then the further development of that process is no longer a direct concern of the Office of Saline Water. Although small percentage reductions in cost may still be indicated, the application of that process to water needs, and the continuing refinements to the process through improved fabrication techniques and engineering improvements that accrue from experience is clearly industry's domain.

To make progress toward our program objectives, we propose a three-prong attack with short-, intermediate-, and long-range goals. Our short-range goal is to develop processes and plant designs which will provide the lowest possible desalting costs at the earliest possible time. To accomplish this, we must undertake a dynamic engineering effort to evaluate the significant amount of research and development technology acquired through this program to date and to choose that which is best for immediate incorporation into the conceptual design of a desalting plant sized in the range of at least 50 times larger than those we are now demonstrating.

A first and important step in the short-range program is the construction of an advanced technology plant to replace the demonstration plant which was moved from San Diego to Guantanamo.

We operated the San Diego plant 12 days less than 2 years. During that period the plant produced a total of 516,950,000 gallons of fresh water from the Pacific Ocean, but far more important than the water produced is that the plant provided important technical, operating, and economic data.

Shortly after the plant began operating, it reached its design criteria by producing, in extended runs, 1 million gallons of fresh water daily. New technology and improved operating techniques developed through the research and development program of the Office of Saline Water enabled the operating contractor to increase the operating temperature of the plant from 190° to 250° F. At this higher temperature, the plant produced up to 1.4 million gallons of fresh water in a single day. During the last several months of operation the plant regularly produced fresh water at 25 percent above its original design capacity.

The capital cost of the improvements and modifications to the plant through which we achieved this substantial increase in production was only \$5,600. We did slightly increase our operating costs to achieve this production rate. It required that we provide steam at a higher temperature, increase the amount of chemical additives, and pump more water through the plant. These capital and operating expenses were negligible compared to the 250,000-gallon-water bonus the plant produced each day.

When the Cuban crisis arose, we had already planned extensive modifications to the San Diego plant, because we had extended the development of the multi-stage flash distillation process as far as the available equipment would permit. The transfer of the plant to the Navy was made in good faith to help solve a difficult water supply problem. We also thought there was an understanding that a replacement plant would be built as quickly as possible. We propose to build the replacement under the authority contained in Demonstration Plant Act (Public Law 85-883) which authorizes \$10 million for the construction of "not less than five demonstration plants." The five plants we have built were constructed at a total cost of \$6,779,858, leaving an unappropriated balance in the authorization of about \$3.2 million.

To call this proposed plant a "replacement" is actually a misnomer. We do not intend to replace the original San Diego plant in the true sense of the word. We will replace the vehicle or the test bed through which we expect to continue the improvement of the multistage flash process with a plant of advanced design.

Until this unusual emergency developed, we had no intention of building a sixth plant under the provisions of Public Law 85-883. We had expected to build all future plants under the authorization contained in section 2(c) of the Anderson-Aspinall Act (Public Law 87-295) of 1961.

If the San Diego plant had not been moved, we would have proceeded with the modifications we had planned. We envisioned the transfer as an ideal opportunity to replace the plant with a plant of new design with which to continue the technological advancement of the multistage flash process. As the situation now stands, we have neither the old nor the new. If the proposed new plant is not built, our program will not stop, but we will certainly extend the engineering odds on the design of large modules. We will also lose the opportunity to develop valuable information for the design of small plants in the 3 to 5 million gallons per day range for which a need now exists. The architect-engineering work on the replacement plant has been completed, and we are prepared to proceed with construction on short notice. Without the data the replacement plant can provide, in terms of time, we may have to slip the whole program. This would have two adverse effects: It would cost more to conduct a longer program, and we would fail to meet the target dates set forth by the President for the construction of a plant of 50 million gallons per day or larger. The technology we expect to gain from the replacement plant will have a direct bearing on the overall efficiency of equipment needed to meet the requirements of the Metropolitan Water District of Southern California, as well as other areas where the need for large-size plants is evermore apparent.

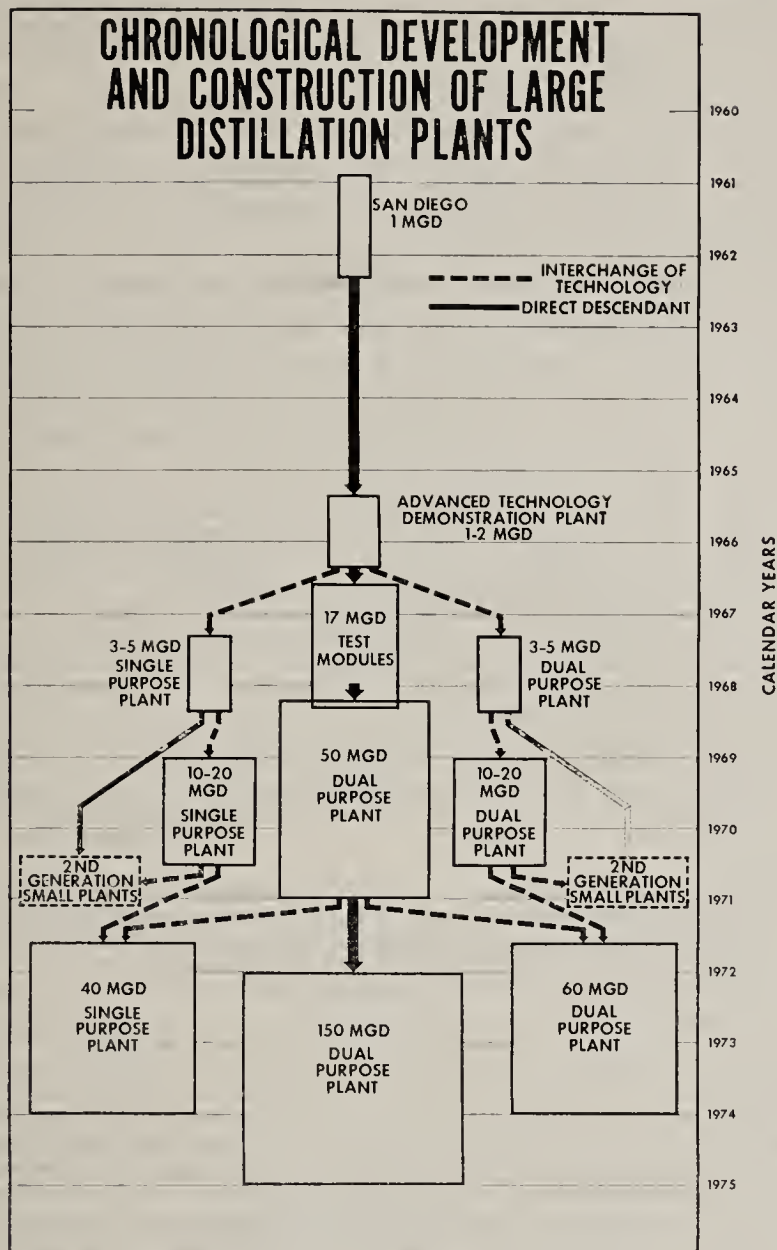
Through the construction and operation of the proposed plant, we intend to push multistage flash technology considerably beyond that obtained in the original San Diego plant. It will provide operating data on a practical scale with higher temperatures and pressures, up to 350° F. compared to the previous maximums of 250° F.; twice the efficiencies, 66 flashing stages compared to 36; and a 20-to-1 performance ratio in contrast to the 10-to-1 performance ratio for the old plant. Operations at higher temperatures is not a panacea but we must find out what happens at the higher temperatures. All of these improvements will be accomplished with a sizable reduction in overall dimension of the flashing stages. We are not talking about long-range scientific developments, but rather engineering refinements that we believe are within our immediate grasp.

Preliminary indications of the economies obtainable in large-size dual-purpose plants have been set forth in studies prepared by contractors for the Office of Saline Water, as well as in the publication "Large Nuclear-Powered Sea Water Distillation Plants," a report prepared following a study sponsored by the President's Office of Science and Technology. More importantly, two major water supply agencies—the Metropolitan Water District of Southern California and the Government of Israel—are seriously considering the construction of large dual-purpose desalting and electric power plants.

Since it is fairly obvious that the first large desalting plants in the United States will be located in southern California, plans are rapidly moving ahead for the establishment of a west coast test center where the necessary preliminary engineering developments based on conceptual studies, the San Diego replacement plant experience and inputs from our research and development programs must be accomplished before we will propose the design and construction of a large plant. This work will include the construction and operation of several modules of the full-size plant to develop as economically as possible for the several processes in development, accurate information on design parameters such as hydrodynamics, heat balance, salt scale, and corrosion control and to identify operating conditions most influential on cost and performance; such as, temperature, flow rate, blowdown, and concentration factors.

Models of other processes and necessary equipment may also be constructed. We intend to test only those processes which can be effectively scaled up or down for economic gain. The chronological development and construction of large distillation plants is outlined on this chart.

(The document referred to follows:)



“CHRONOLOGICAL DEVELOPMENT AND CONSTRUCTION OF LARGE DISTILLATION PLANTS

“The attached chart depicts the programed stepwise engineering developments leading to the construction of large-scale desalting plants.

“The original San Diego 1-million-gallon-per-day plant provided solutions to many problems, including (a) those encountered in higher temperature operation (up to 250°F.) with acid treatment to prevent scale formation, and (b) those involving control of brine level and ways to maintain equal distribution of vapor flashing in a large number of evaporator stages. The plant also provided operating experience in the areas of corrosion control and maintenance requirements.

"Development work will continue through the time period indicated on the chart. This involves a logical progression of experience and technology through an advanced technology demonstration plant of 1- to 2-million-gallons-per-day capacity; a module test program; a 50-million-gallon-per-day prototype plant; and finally a 150-million-gallon-per-day plant.

"The advanced technology demonstration plant is a follow-on plant to push multistage flash technology considerably beyond that obtained in the old San Diego plant. It will provide operating data on a practical scale with higher temperatures and pressures (350°F. versus 250°F.); twice the efficiencies, 66 stages and 20-to-1 performance ratio in contrast to 36 stages and 10-to-1 performance ratio for the old plant; a sizable reduction in overall stage dimensions; and more sophisticated instrumentation.

"One or more large test modules will be built, based on experience gained from the advanced technology demonstration plant and the conceptual design studies now being prepared under contract for OSW. Modules consisting of an integrated arrangement of full-size components, such as pumps and flash stages, will be built and operated to insure satisfactory performance before committing ourselves to an expensive prototype plant. The 50-million-gallon-per-day prototype plant is expected to be a production plant incorporating the best features of technology derived from the demonstration plant and test module.

"Much of the experience and technology obtained from the central development program will be advantageously used in concurrent design and construction of smaller plants in the range of 3- to 20-million-gallon-per-day, single- or dual-purpose plants, thus providing a balance to the program which will develop desalting processes to meet a variety of size requirements."

As the proposed 50-million-gallon-per-day plant may, in fact, be a module of still larger plants, we need data for the determination of optimum engineering technological parameters, optimum modular size, the maximum size of a single hydraulic system, and the achievable economic gain as a function of size and maximum operating temperature.

Three large-scale plants will be necessary to advance the purposes of our act, assistance from the Office of Saline Water, or whether they will be constructed by the Office of Saline Water with assistance from a local utility organization is not clear at this time. In either case, we cannot proceed with this type of construction program without first returning to Congress for further authorization.

When this type of information has been established, we then have the opportunity to select the most economic and reliable operating conditions. For example, we will reach a point in operating temperatures where steam pressures will require stronger and more costly hardware, but the upper limits must be established so that we can determine the engineering trade-offs we need to make for optimum economy.

We have no intention of proposing the construction of a large prototype plant simply to prove out quantity production. Our sole interest will be to demonstrate the achievement of the lowest price water possible through the best use of available technology. It is our present conclusion that the status of engineering development needed to support the construction of an economical 50 million gallons per day plant or larger has not yet attained the appropriate level of advancement unless one is willing to take high technological risks. Optimistically, today's status of engineering development might warrant design and component fabrication scale-up and construction of two 25 million gallons per day sections unitized into one plant. Any of these configurations would certainly provide cheaper desalted water than can be produced by an existing plant, but at this point in time we believe additional engineering on properly sized modules, such as we have included in our short-range program, will be better both technically and economically.

The intermediate range program will be conducted through experimental pilot plant operations and utilization of hardware components that will develop new technology for application in the period 1972 to 1975. Some of this development work will parallel engineering studies conducted for the short-range program. There will be a close intertie between the two, but the longer range of the intermediate program will enable us to work with processes that are still very much experimental in nature, but which have good potential with further development. More time is needed to develop modifications and improvements to fully determine the technical merit and economic potential of these new approaches.

The long-range program is centered in basic research. Through a dynamic

program of fundamental studies, we hope to develop entirely new approaches to the desalting program. This information will be utilized as quickly as it is available, but realistically, most of it will not have an impact on desalting technology until 1975 and beyond. Except in unusual circumstances, there is a long development period between the glassware of the laboratory and the hardware of a commercial plant, but the path to technological advancement in our day has been blazed by research. It would be foolhardy to ignore its long-range potential.

From my review of the operations of the Office of Saline Water to date, I am most impressed by the working partnership it has established with private industry. Much of the expertise that industry now has, is to a great extent a direct result of its involvement in the Department of the Interior's saline water conversion program. Though the development of advanced technology, such as that which has become available through the construction and operation of the Freeport and San Diego plants, U.S. firms have made substantial inroads on a competitive basis for plant construction in the international marketplace. The market today, however, is minute compared to what it will be as further development drives down the cost of desalting water. Plants that have been built to date, and those that are being planned, are feasible only in areas where natural fresh water is limited in supply and high in cost or polluted. The size of the future market for desalting equipment is in direct proportion to the cost of product water.

There are some who believe that the distillation process is ready now for utilization in plants of 50 million gallons per day capacity or greater. I expect that this committee will receive statements to that effect at this hearing. I do not intend to dispute their position; in fact, we are delighted that some industrial firms have decided that they have the capability to provide an installation of that size. I would like, however, to add this thought, which I hope is not construed to be pessimistic, but rather as a word of caution.

The jump from present 1 million gallons per day plants to the 50 million gallons per day size or larger is not beyond the realm of engineering feasibility. Certainly, the turnkey construction of such a plant can be guaranteed, but more important than its construction are the questions of capital investment and cost of water. If at some location, either in the United States or abroad, there exists an immediate need for such a plant and the cost of product-water is not an overriding consideration, we are confident that a plant of this size can now be built.

The Office of Saline Water has made a continuing effort to stimulate the participation of industry in the saline water conversion program. Our role certainly is not to create a monopoly for a few companies, who through their activity in this field to date may find that they have a competitive advantage. This advantage relates only to the high-price fringe market. Only a few of the potential processes have reached any degree of refinement, and the demand for water will be such that it will be absolutely necessary to create a range of processes to meet a variety of conditions. We think this can be best accomplished by broadening the industrial base. There does not exist a semblance of developing competition, but there are many competent companies that are just now beginning to direct their extensive talents to desalting problems. The Federal program can stimulate their interest in today's program just as it advantageous has engaged the attention of industrial organizations in the past.

The limited business opportunities that have been available to date have already indicated a trend toward competitive bidding, but financially attractive bids have been weighed against competence, and the competence that has resulted from experience has been a more overriding consideration than cost. With an expanded desalting program many more firms will develop desalting proficiencies; without this spur, few, if any, additional companies would enter this field of enterprise.

To meet our responsibility to the President, the Congress, and in turn to the taxpayer, we believe it would be unwise for us or anyone else to proceed with the construction of a large plant unit until we have collected all usable data from available technology and refined it to point from which we can move forward with assurance that the plant we build will represent the most advanced extension of the art within the bounds of sound engineering extrapolation. While we agree that a 50-million gpd plant can be built today, we believe the intermediate steps that we propose to undertake, before proceeding with a plant of that size or larger, and which we believe is beyond industry's ability to sponsor, will provide a far more efficient plant than can be designed with the best technology available today.

Aside from the technical aspects of the program, we must at least in a preliminary way, analyze the water supply situation. It is obvious that the principal customer for desalting plants will in all probability be a political subdivision of government. Thus, we plan to do more in such areas as identifying water needs, conveyance costs, alternative water sources including reclaiming waste water and the related economics. This will be done in concern with other bureaus of the Department of the Interior and other Government agencies.

The factors that influence the cost of water to a customer can be conveniently divided into two main areas: First, factors that occur "within the skin" of the desalting plant itself, engineering optimization of such effects as heat transfer rates, steam temperatures, chemistry of feed water, scaling, corrosion, fuel cost, construction costs, and many other factors. The second area of consideration includes factors that bear directly on the cost of water, but are outside the characteristics of the desalting plant and over which we exercise no control. These are the cost of money, the amount of water needed for a specific area (i.e., size of plant), the availability of a properly sized storage and distribution system, the geographical need for blocks of power in the case of a dual-purpose plant. Much too often only the first area is considered and the second is ignored.

The present authorization of the Office of Saline Water, Public Law 87-295, contains the following statement: "As used in this Act the term 'saline water' includes sea water, brackish water or other mineralized or chemically charged waters." We intend to work on the development of processes which will have application for demineralization of all types of waters contained in that definition. We especially intend to increase our activity in brackish water areas, and take a hard engineering look at the potential application of desalting processes on acid mine waters, in tandem with the effort on large plants. We propose to maintain a balanced program. To expedite our investigation of the applicability of sea water desalination techniques to a brackish water treatment, we will establish a test center for brackish water similar to our Sea Water Conversion Research and Development Test Station at Wrightsville Beach, N.C. Our experience at Wrightsville Beach has established the value of such a center to carry out efficiently the large pilot program and test bed phases of our development program. Because of the nature of the processes applicable to brackish water desalination, the size of the brackish water test center and equipment will be much smaller than that of our Wrightsville Beach Test Center.

Engineering evaluations and whatever other studies or activities may be necessary to determine the potential use of desalting processes for the reclamation of acid mine waters which are choking the rivers of Appalachia will be forthcoming: in fact, some engineering evaluations in cooperation with the Bureau of Mines and the State of Pennsylvania are already underway.

While desalting plants are now producing fresh water on a commercial basis at a number of locations where water is in short supply and very expensive or where the quality of water is poor, the cost of desalting sea or brackish water today is still too high for general municipal and industrial use. Factors which will affect the performance capabilities of processes include not only the type of mineralization and degree of salinity of the water to be desalted, but also the purity requirement of the product, the size of the plant, the cost of fuel, the temperature of the raw feed water, and whether it is the sole source of supply or incremental supply, single or dual purpose. Some processes may be adaptable to meet a variety of these conditions, but it is highly unlikely that a process will be developed to best meet them all; thus we foresee a need for a family of processes for a variety of applications, each tailored and developed to more economically answer a specific water supply situation.

There are a number of methods through which saline water can be desalted: some of them have been known for centuries, some are fairly recent, some are new; but none have yet reached their full economical potential. It has been easy to predict the eventual achievement of low-cost desalted water, but to produce it is something else. The chronology of development of several processes has followed a reasonable engineering pattern, but actual progress has never quite been able to meet optimistic economic projections.

The economic studies we have conducted to date have been able to consider only a small fraction of the overall problem. It is not always practical to attempt to assign a reasonable market value to water. One thing is absolutely clear: there is no water as expensive as no water. Each summer we read of water use restrictions imposed by various municipal governments. We can

expect to read about, or perhaps even endure, these restrictions as long as periods of drought or extended heat waves cause supplies of fresh water to be consumed at a faster rate than our natural resources can provide.

The cost of water itself becomes less important when considered in the light of the economic impact of water rationing. Many industrial plants require great volumes of water for processing, and water use restrictions can cause production cutbacks which diminishes profits and paychecks.

But even more important than economic considerations is the relationship of water supply to human needs, especially the detrimental effects on health that can result from water shortages. Inadequate supplies of fresh water serve to compound pollution control problems. Without sufficient water for dilution of the effluents we pour into our rivers and streams they can become so choked with pollutants as to lose their natural ability to regenerate the water to a usable condition. To alleviate this adverse situation, we suggest that it is now time for saline water conversion plants to be considered as a practical supplemental source of fresh water supply.

We do not intend to imply that the Office of Saline Water should enter the water supply business through the construction and operation of desalting plants, but we do recommend that the technology which is now available be utilized advantageously. To accomplish this, the Office of Saline Water is prepared to provide technical assistance to other Government agencies.

Federal programs to make water available are now being conducted by the Bureau of Reclamation, the Corps of Engineers, the Department of Health, Education, and Welfare, and the Housing and Home Finance Agency. These programs include such activities as the construction of dams to create fresh water reservoirs, grants or loans for sewage and water treatment plants, distribution facilities, etc.

As a specific example, the Housing and Home Finance Agency recently provided a grant and loan to the Port of Mansfield Public Utilities District of Raymondville, Tex., for a complete water treatment facility, consisting of water supply well, iron and manganese removal filters, two 100,000-gallon concrete storage reservoirs, and a 250,000-gallon-per-day electrodialysis process desalting unit. The HHFA contacted the Office of Saline Water for general technical advice in the selection of the process to be used at Port Mansfield. Unfortunately, no contractual provision was made by HHFA to provide for the availability of technical data on the operating characteristics of this plant to our Office. Such data can often provide valuable technological spin off and in all future projects of this kind we will strive to obtain arrangements which will provide us with such data.

We are not advocating any new loan or grant programs. The mechanisms for this type of assistance may already be vested in other agencies. But we would like to have the opportunity to participate in the design, construction, and operation of conversion plants or at least to receive, as previously mentioned, technical and economic data from plants which are built or funded by other Government programs.

We do not intend to spend appropriated funds on the development of any process unless we can be reasonably assured that it will better meet a specific need than any other process. Our continuing critical analysis of processes potential may require us to reevaluate some of the strategy we now plan, but this is normal in any progressive activity. We must remain flexible and ready to exploit any advantageous shift that may develop as a result of the research and development we sponsor.

I would find it difficult to assess priorities to small and medium sized brackish and sea water plants on one hand and large single or dual purpose sea water plants on the other. There are many valid reasons that have prompted us to reach that decision. Brackish waters is a term we use to describe a broad range of salt polluted water. The Public Health Service has established standards that good drinking water should contain not more than 500 parts of dissolved salt per million parts of water (500 p.p.m.) and further, that water containing more than 1,000 p.p.m. should not be used for human consumption.

Potential users of saline water conversion plants (100,000 g.p.d. and up) include municipalities and other public or private water utilities providing water supplies to domestic, institutional, commercial, or industrial users. These may use desalting facilities to supplement an inadequate existing water supply, to improve the quality of an existing supply, or for both purposes. It is antici-

pated that cost comparisons with water from conventional sources will not always constitute a limiting factor to the utilization of saline water resources. Eventually, every major water utility may incorporate a desalting unit in its treatment plant. A water-quality conscious population is likely to insist on higher than minimum water-quality standards.

Industry has water quality requirements which may be quite different from those of residential water users. Cooling water can be less pure than potable water. Boiler feed water, water for chemical processing, and water for canning and soft-drink production must be substantially purer than most potable water and it has a higher economic value. Thus industry may profitably employ additional demineralization equipment as the economics of demineralization systems are improved. Also, the Government, including the military and civil defense, is a prospective user of desalination facilities. Additionally, power utilities may wish to expand the market for their product by building and operating dual-purpose desalination facilities. Sewage treatment for municipal water reuse may need to be complemented by desalination, especially in closed-cycle, indefinite reuse, water systems.

Pollution abatement for America's streams represent a need which may be met in part through desalting facilities. Whether the pollution is due to sewage or treated sewage effluents, to industrial wastes, or to acid mine drainage, it is probable that saline water conversion techniques will find applicability in the scheme of cleaning up rivers and lakes.

The evaluation of all possible alternatives to arrive at an optimum regional plan is a difficult task which will require much care and consideration. For example, the evaluation of the alternatives of fresh water redistribution and sea water desalting will require a careful assessment of the cost of delivery of these alternative water sources to all points to be served within the region to determine the economic boundary lines. This table lists the input data required and the decision steps necessary for economic optimization of a given site. In certain areas, the economics of reclaimed water must also be analyzed and understood.

(The table referred to follows:)

ECONOMIC OPTIMIZATION FOR A GIVEN SITE

Input data required:

1. Water needs:
 - a. Time phasing.
 - b. Quantity.
 - c. Quality.
 - d. Demand schedule.
2. Power needs (if any).
3. Alternative sources of fresh water and incremental cost.
4. Water storage and distribution capacities.
5. Saline water availability.
6. Brine disposal possibilities.
7. Cost of energy.
8. Value of incremental water.

Decision steps:

1. Select water source.
2. If desalting selected, determine:
 - a. Plant size.
 - b. Public or private funding.
 - c. Dual or single purpose.
 - d. Location.
 - e. Desalting process.
3. Determine cost of incremental water.
4. Recycle.

A number of foreign countries have an urgent need for desalting facilities. In some areas, the limitation of cost competitiveness has been removed because potable water resources are not within reach. The desalination of brackish waters presents a variety of problems. But more importantly, it also provides some exciting opportunities. First of all, there is an enormous amount of brackish water readily available to the United States; second, much of this water is available in areas where natural fresh water is in short supply; and third, most brackish water is in the salinity range (1,500-6,000 p.p.m.) which may be desalted and put to practical use at a feasible price.

Relative to the economics of sea water desalting, this table interrelates quite well, I believe, in an approximate manner the current economics of a wide spectrum of water uses, the complexity of our mission to develop the technology for desalting systems which meet or better these economics to serve each of the needs shown and an order-of-magnitude estimate of each time period by which we expect to have desalting units that meet these capacity ranges and water costs.

Time period	Water cost per 1,000 gallons (sea water)	Type of utilization	Typical plant size (million gallons per day)
1952-----	\$5.00	Remote small community (e.g. islands)— Tourist or export economy.	0 to 0.2.
1965-----	1.00	Isolated small communities—Industrial economy.	0.2 to 1.
1968-72-----	.50	Small communities—Industrial and residen- tial.	1.0 to 10.
1970-75-----	.25	Large municipalities—Developed economy--	10 to 150.
Beyond 1975-----	.12	Agriculture—High value crops-----	150 to 1,000.
	.06	Agriculture—Low value crops-----	1,000 and up.

It may be seen that our current status of desalting development has brought us to the stage where desalting plants of American design and manufacture can be purchased and installed to economically serve the fresh water needs of small communities (upward of 5,000 population) isolated from natural fresh water supplies. By 1968-72, we expect to have developed and field tested the technology to support the manufacture and sale of desalting plants big enough to supply the industrial and residential needs of larger communities, those in the range of 10,000-50,000 people.

This table represents by percentages the distribution of funds required to maintain a balanced program.

Fund distribution as to functions by short, intermediate and long-term goals

	Percent, short range	Percent, inter- mediate range	Percent, long range
Distillation-----	56	48	-----
Membranes-----	8	20	6
Special projects-----	3	10	36
Engineering services-----	15	-----	-----
Other R. & D.-----	18	22	58
Percent of total-----	40	40	20

This distribution is necessary in order to obtain maximum benefits from the short, intermediate, and long-range programs we have planned. Any sizable deviation from this distribution would tend to overemphasize one function at the expense of another.

The established target for the short-range distillation program is to conduct the development work which will provide the technological information and engineering data that we must have to initiate the construction of a 50-million-gallon-per-day plant or larger in 1968. This is a demanding deadline, but it is one we intend to meet. Throughout the short-range program, we will continue to press forward with the development of improved technology on processes other than distillation that will be needed to meet a variety of water supply problems.

The percentage figures we are providing the committee on this table can only approximate the rate of expenditures for the years ahead.

Distribution of program funds by functions

[In percentage]

	Fiscal year 1967	Fiscal year 1968	Fiscal year 1969	Fiscal year 1970	Fiscal year 1971	Fiscal year 1972
Administration.....	4	3	3	3	3	4
Program analysis.....	2	2	2	2	2	3
Research.....	23	20	27	26	26	35
Engineering analysis.....	1	1	1	1	1	1
Engineering services.....	8	5	7	6	5	5
Distillation.....	40	51	35	36	40	24
Membranes.....	13	10	13	14	9	10
Special projects.....	9	8	12	12	14	18

They are not precise simply because we cannot foretell the rate of technological development in all areas. The percentages we have projected may deviate as much as 10 or 15 percent depending on the accuracy of our planning. We will program our funds to obtain a maximum amount of technological progress toward our target. The cost of hardware, particularly in those years we awarded contracts for major plant components, will cause the annual rate of expenditure to vary considerably; we know at this time when the funding will peak.

Several members of my technical staff are here with me today. Following these general remarks concerning our program plans and objectives, we will be pleased to respond to any questions members of the committee may have concerning specific details of the work we have programmed to advance desalting technology. We have devised a program which we feel will meet our commitments to our own public customers and foreign countries as well.

Saline water conversion plants will, in my opinion, become an important part of our future domestic water supply and at the same time serve as a notable extension of U.S. foreign policy. The work we engage in to sharpen technology to its most effective point will help raise to greater esteem our national prestige in the family of nations, especially in those countries where the thirst for water is already critical. It is my hope that every time a human being in a foreign land swallows a mouthful of fresh water obtained from a plant based on U.S. technology he would savor the genius and humanitarian generosity of this great Nation.

In the letter which transmitted for consideration of the Congress the legislation which is the subject of this hearing today, President Johnson reiterated his often stated aspirations for the desalting program when he wrote:

"By pressing ahead with a vigorous program of economic desalting to meet our ever-growing needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

"It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage."

Mr. DI LUZIO. Mr. Chairman and members of the committee, I have only been with the Office of Saline Water for 4 months. One of my first functions in the Office of Saline Water, was to bring myself up to date on the state of the art, on our relationships with other Government agencies and with industry; to ascertain the possible market for plants, and determine which processes had the best potential, which programs should be funded in terms of engineering development and which should be funded in terms of research and development.

I also looked at the work being done by foreign countries, the Russian results, the work being done by England and Israel, which I had been familiar with before, and the agreements we have with respect to Mexican and other studies. I have brought myself up to date on all these agreements with various countries in terms of various kinds and sizes of plants that they were planning.

I think one of the best bellwethers of international interest in the desalting program is the tremendous response that we have had to the first International Symposium on Water Desalination which will be held in the United States in October. To date we have received official lists of delegations from 53 countries. Without question there is tremendous interest in desalting technology throughout the world and in this country as well.

We are constantly receiving letters from foreign governments and from other agencies of our own Government and governmental subdivisions requesting information on our processes and their possible application.

We are continuously working very closely with the Department of Health, Education, and Welfare on water pollution questions, because I am sure that some of our processes will help solve some of our pollution problems.

We have also worked with the Bureau of Mines and the State of Pennsylvania and other States to study the acid mine water problem. Perhaps we don't have the full answer to the treatment of acid mine waters, but we certainly have a partial answer in being able to provide the communities on the banks of these streams with potable water from these polluted streams.

I think I would be less than honest if I told you that we have answers to all the problems that we see. We don't. We think, however, we have the means of arriving at the answers.

In reorganizing the Office of Saline Water, one innovation that we have added is an Engineering Advisory Committee made up of active, experienced professional engineers to examine our engineering development program. We have also appointed very responsible and knowledgeable people to scrutinize our entire research program to see whether or not we are doing research in the correct disciplines or in the proper magnitude. This is going on now, and it will continue for the next 30 to 60 days. When these evaluations are completed, we will be able to pass judgment on our research program as it is now constituted. Any changes that are indicated will immediately be put into effect and priorities on various projects will be established.

We also have engineering committees investigating each of the process categories independently including distillation, freezing, membranes, and ion exchange.

We are reviewing the state of our technology before we utilize any of these processes in expensive hardware.

Our current program—and when I say “our current” I am talking about the short-range program which covers the next 5 or 6 years—is largely an engineering oriented program. It will take existing processes and really engineer them properly to get the best results from them.

This will result in a need for actual demonstration of processes in reasonable sized plants, because just as our experience at San Diego indicated, we can study things on paper theoretically for months and months, but there is no substitute for an actual operating plant under actual conditions. A little later I will discuss the San Diego plant and what it has meant to the program.

In analyzing the proper role of the Office of Saline Water to develop desalting technology in relation to that which industry can most ad-

vantageously perform, and this analysis has been conducted by conversations with the industry representatives and with other departments of Government, we generally find an agreement that the Office of Saline Water must bear the major responsibility for proving out a process. I don't think that it can be done by any other method. The basic process, the basic economics, the basic design, at least through the first generation development of a process must come from the Office of Saline Water. I would like to point out that we do not build plants; they will be built by private industry on competitive bids, but developing the design and the economics, I think, is the responsibility of the Office of Saline Water. The improvement of the plant, which is something second or third generation plans will produce, is probably more in the domain of private enterprise than in the Government domain.

To reach this point of technical and economic development, some processes may involve only the construction of first generation plants.

Other processes may require the construction and field operation of several succeeding generations of plants. The engineering economics of a process must be developed to a practical basis. In my opinion a practical range is when we bring water down to a reasonable price bracket for municipal and industrial water. It would not include agricultural water.

Although a percentage reduction in cost may still be indicated, once we get the basic price down in the range of 30 to 35 cents—and someone may propose a method of reducing the cost 2 cents more—I don't think that the Office of Saline Water ought to participate in that kind of a project. I think this is where industry, using its genius for lowering the manufacturing cost and the material costs, can best apply itself. Once we bring the price to a reasonable range, from then on that process should be in the domain of industry, and it would be up to them to refine it and improve it. Competition between various companies will continuously keep whittling away at the cost. I don't think that we should build second and third generation plants to make minor reductions in the cost of water.

To make progress toward these objectives we propose a three-pronged approach with short, intermediate, and long-range goals. The short-range goal is to develop processes and plant designs which will provide the lowest possible desalting cost at the earliest possible time.

To accomplish this we must undertake a dynamic engineering effort to evaluate the significant amount of research and development technology acquired through this program to date and to choose what is best for immediate incorporation into the conceptual design of a desalting plant sized in the range of at least 50 times larger than those we are now operating.

A first and a very important step in the short-range program—this is the next 5 years—is the construction of an advanced technology plant to replace the demonstration plant which was moved from San Diego to Guantanamo.

The data on this one—which I would like to submit for the record—is that the San Diego plant was operated for 2 years and produced 516 million gallons of water. The improvements we made to the San Diego plant required a moderate expenditure of \$5,600, which in-

creased its basic design capacity from 1 million gallons per day to 1,250,000. Under ideal conditions it hit peaks of 1,400,000 gallons per day.

(The information referred to follows:)

SAN DIEGO (POINT LOMA) SEA WATER CONVERSION DEMONSTRATION PLANT

Design capacity 1 million gallons per day (g.p.d.).

First annual report January 1962 through June 1963 No. 71.

Second annual report July 1963 through February 1964 No. 100.

First operations (other than testing) March 5, 1962.

Dismantling for transfer to Guantanamo Bay started February 27, 1964.

A. & E. contractor—Fluor Corp.

Construction contractor—Westinghouse Electric Corp.

Management, operation, and maintenance contractor—Burns & Roe, Inc.

Multistage flash distillation process.

Most production in a 24-hour period, 1,400,000 gallons, May 2-3, 1963, with brine outlet temperature of 240° F.

Highest monthly production 25,600,000 gallons, April 1963.

Total plant output sold to San Diego 516 million gallons during period, March 1962 through February 1964. To produce this amount of product water, only 71.1 percent of plant capacity was utilized.

Most downtime was caused by marine vegetation, sand, and silt interfering with continuous operations.

Plant is capable of continuous production at a rate of 1,250,000 gallons per day and has a potential of 1,400,000 gallons per day.

Major modification accomplished:

Installation of pH control equipment.

Retubing of air ejector condenser.

Design and fabrication of intake pit airlift.

Capital cost, \$1,907,000.

Demonstration plant operating cost (1 stream-day—300 operating days per year):

Direct operating cost per 1,000 gallons.....	\$0. 79
Indirect operating cost per 1,000 gallons.....	. 73

Total operating cost.....	1. 52
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Cost per 1,000 gallons, 6-month progressive average

	With amortization	Without amortization
Lowest months, May and September 1963.....	\$1. 71	\$1. 27
Highest month, March 1963.....	2. 17	1. 57

Mr. DI LUZIO. To call the proposed San Diego II plant a replacement is actually a misnomer. It is not a replacement plant, because it is not the same kind of plant as San Diego I. It is a plant which is really a second generation, multistage distillation plant. When the first plant was transferred from San Diego, the Office was already in the middle of plans to make major modifications that would provide an opportunity to operate the plant at higher temperatures, and other process improvements which would demonstrate that we could get more water out of this size plant at lower cost.

In the meantime, of course, the plant was transferred. So we wound up with neither the old plant to modify nor a new plant in which to try this new technology which we think is very critical to the design of large plants. There is also a need for this process information for the design of 3- to 5-million-gallon-per-day plants.

Through the construction and operation of this new plant we expect to push the multistage flash technology considerably beyond that of the original San Diego plant. It will provide technical operating data on higher temperature and pressures.

Operating temperatures of the modified San Diego I were increased from 190° to 250° F. The new plant will begin at 250° F. with provisions to increase to 350° F.

It will have twice the efficiency. It will have 66 flashing stages instead of 36. It will have a 20-to-1 performance ratio, which means for each pound of steam we will hope to get 20 pounds of water instead of 10 pounds of water for each pound of steam produced by San Diego I.

I would like to point out, however, that there is no magic in simply increasing temperatures, it is not a panacea to the water desalting problem.

By pushing up to higher temperatures we will find the upper limit at which we can operate economically without scale or corrosion. We must establish the upper parameters of temperature operations, because once established we can back off to a point of greatest operating efficiency.

Another thing that we hope to do when we rebuild the San Diego plant is to show that the new module will produce 1 or 1.2 million gallons of water with about a third of the cubage of the old plant. I think we know now how to build a plant which uses smaller evaporator pans, shorter flow patterns, better intakes, and a much smaller hydraulic system.

There are some engineering tradeoffs we can make. We would like to find out through San Diego II what these tradeoffs really are from practical engineering standpoint.

We need to establish a west coast test facility where we can operate modules and models which must precede the construction of the first large plant. It seems likely that the first large plants will be erected in California, for three reasons. One is that they have extremely large cities. Two, they have a water shortage in that part of the country. And three, they have an aqueduct system and distribution system into which these large quantities of water can be fed.

California, fortunately or unfortunately, has both a need for quantity of water that we are talking about and a distribution system in being which will handle it.

The projected requirements for power in that area indicate an opportunity to design a plant loading factor on both the evaporator and the generating units which will provide a highly efficient dual-purpose plant.

I don't think a question asked this morning about building a dual-purpose plant was answered completely. I think several considerations were overlooked. One is that when a generating plant is built during its peaking requirements it operates at its highest efficiency. During offpeak requirements it may have 60 percent of its capital investment sitting idle, which increases the per kilowatt cost of power.

So that if you have a plant which is only needed for peaking purposes, it sits idle except for a few times during the 24-hour cycle. One of the economies we get out of a dual-purpose plant is better utilization of the steam generator.

There are other economies in dual-purpose plants, powered by large reactors. One is that if we have a water plant associated with it we don't have to build condensers, which are very expensive pieces of equipment. We also can bleed off steam from the final turbines for better use in the waterplant because these are the high-cost phases of the electric generation cycle, and they produce the lowest efficiency in terms of generating capacity.

If we build a plant which has a dual purpose in a very expensive land area like California, it would be better to build one plant to serve many purposes instead of having two areas of expensive land tied down, one for water and one for power generation.

The interties between power blocks is another factor. Power can be transferred during an offpeak load cycle from one center to other centers which are hitting peaks. This is also an economic factor.

There is the possibility of operating two or three different processes at the same time. We can build a larger evaporator powered by a reactor to distill water. We also can take the turbine shaft and extend it, put a vapor compression plant at the end of it and use the mechanical energy of the spinning gears to produce water.

We can take offpeak power from an atomic reactor and carry it considerable distances to brackish water plants which use electric energy.

The point I am trying to make is that no one has really thought out the best total arrangement of a dual-purpose plant incorporating all of these ways of getting the fullest efficiency out of available power. This is one of the biggest phases of our program, to take a look at water requirements and see how we can best solve, not only sea coast city problems, but also inland brackish water problems. There are schemes afoot which indicate that we can really get low-cost energy to operate machines or processes which are very favorable.

I am sure you will hear industry witnesses who will say that they are now ready to build a 50- or 100-million-gallon plant with no further technology. I would have to say that perhaps they can do this. There is no magic in building it, but I wouldn't know how to evaluate the economics of such an offer. I would hate to have us gamble on doing it right now. It would be a first-generation plant. It would have bugs in it just like any first-generation plant.

The proposal we are making, to go from 1 million to a 17-million-gallon module and then to a 50-million-gallon-per-day pattern, a size in which the Metropolitan District is interested, is a logical program for two reasons. One, we are doing it step by step, and I think will provide surer results.

Two, in designing San Diego II, it will give us an idea of how to build a very efficient 3- to 5-million-gallon plant using that advanced technology, than by going to a 17-million-gallon module plant, one-third the size of the 50, we will have solid data for a 15- to 20-million-gallon plant. Those are all things which will spin off from the central program.

Now, the intermediate range program is one which I think will provide plants for the 1972 to 1975 era. It will involve new engineering concepts. It may be a distillation process or a membrane process, but it will involve new things that we haven't thought about from the equipment standpoint.

The long-range program is basically a research program. This is our only hope for coming up with processes beyond 1975 that can be placed into pilot plants and demonstration plants which hopefully might eventually lead to water at 20 or lower cents per thousand. We don't now know how to even approach agricultural water. I think Congressman Aspinall's point this morning was well taken, that it may be 1980 before we even begin to have ideas about this. We are saying it is beyond 1975, but our only hope to ever be able to do this is through a good, well-rounded, well-balanced research program such as we have now.

Someone may come up with an idea that might make this feasible.

As I pointed out before, I think you will hear witnesses that will say they can build a plant and guarantee it. I think we have a much better way of approaching it, a safer way of approaching it.

There are two kinds of economics affecting the cost of water which I would like to identify. One is the economics which I would like to state as being "within the skin of the plant." These are the economics that can be solved by good engineering, good basic research, or good applied research. These economics are based on heat transfer rates, the kind of material one uses, the operating temperature, the chemical processes you use to treat waters so that they don't form scale or pit the equipment. These are the things which we in the Office of Saline Waters feel we have a handle on. We know how to reach those, and I think we can do a very good job on them.

But then there are economics outside the plant over which we have no control. These economics are the cost of money, debt retirement, availability of reservoirs, storage capacity for distribution systems, the size of the plants required for a given need—these we have no control over; these are functions of a specific site or a manner in which a plant is funded. In some cases this may amount to 50 percent of the cost of the water. So when we talk about water cost reduction, we are only talking about reducing the processing cost of the water within the skin of the plant over which we have control. We cannot control this other.

Another very important piece of our program and one which I think has to be emphasized is the approach to brackish waters or polluted waters. Sea water is only one answer, is the answer for only a certain kind of a customer. In this country we have great pools of brackish water. I think they deserve as much attention as sea water. In fact, I think our first large market for plants could well be in the brackish water areas, particularly in the States of Texas, Colorado, New Mexico, Arizona, and Nevada. These pools are rather large. The water is well above the minimum standard set by the Public Health Service for good drinking water. We have a list of a thousand communities where water is over 1,000 parts per million. These are all possible sites for brackish water plants, if we can come up with plants that can desalt water at a reasonable cost of 35 to 50 cents. Most of these will be small plants.

We also have the problem of acid mine waters that I spoke about before. While we don't know the perfect answer to this problem, we do at least know how to provide potable water, and I think we should move into this problem area.

Most of our work in brackish water has been done by extrapolating from sea water information. We find this leaves much to be desired. Brackish waters are extremely complex. Some of the chemicals in brackish waters have to be treated prior to going into the processing plant. Rather than trying to build a processing plant that meets the requirements of all kinds of brackish waters that are in existence, it might be better to work on a process which can handle brackish water of a certain chemical consistency and then come up with pretreatment processes which remove iron and manganese and silicas and other things which foul up the processes so that we can standardize on a plant to some extent and still handle these very difficult waters which are found in North Dakota, South Dakota, New Mexico, and parts of Colorado. I think this is a very significant piece of our work. This is something we have to face up to.

There are a number of methods by which one can desalt water. Some of them are centuries old, and some of them are new, but they all involve engineering to provide usable equipment. It is one thing to have a natural phenomenon on paper, and it is another thing to build equipment. I have had some personal experience in trying to engineer the Zarchin process. And we had to develop the hardware; we had to build it and test it.

There has been some misunderstanding, I believe, in what the program of the Office of Saline Water will be in the area of plant construction. I think I can state this categorically since I have discussed it with Secretary Udall. We do not propose that the Office of Saline Water should enter the water supply business through the construction and operation of desalting plants. We do recommend, however, that the technology which is now available be used advantageously.

The Office of Saline Water is prepared to provide technical assistance to other Government agencies. I will give you an example of this. We have initiated many contracts over the years on reverse osmosis. We know that the Department of Health, Education, and Welfare is now talking to the same contractor's about using reverse osmosis in polluted water control. It seems to me that HEW and Interior ought to be working closer together to exchange this technology as it is developed.

I would hate to see these agencies go on their own each with their own specialists in these various things and get the same information from a contractor which is already available in Government. We are making an arrangement where we will consult with HEW to try some of these processes, using our existing equipment if it is possible, on polluted water.

Perhaps we can take some of these small private plants and put them in a location where we can actually either run acid mine water through them, or polluted water, and just see what they will do. This equipment is ours, it is paid for, and we might just as well use it and see how much of a solution we can offer HEW with no additional expense for the development of equipment.

There are many agencies of Government which have the authority to provide either funds or plans or other assistance to provide potable water to communities. The Bureau of Reclamation, the Corps of Engineers, the Department of Health, Education, and Welfare, and the Housing and Home Finance Agency have the authority. The Housing and Home Finance Agency recently provided a grant and

loan to the Port Mansfield Public Utilities District of Raymondsville, Tex., for a complete water treatment facility, consisting of a water supply well, manganese removal filters, two 1,000-gallon concrete storage reservoirs, and a 250,000 gallons per day electrodialysis desalting unit. I think it is absolutely unnecessary for us to be talking about the right to build plants to serve these needs. There are existing agencies which are in this business, and I cannot distinguish between an electrodialysis or reverse osmosis plant and a normal water supply piece of equipment. They provide the same end product. I would hope that they would look at our equipment, desalting equipment, rather than just looking at the conventional ways of treating water, if we can meet the test of the marketplace for quality water at a given price.

Mr. ASPINALL. Mr. Chairman, at this particular place, I understand that Port Mansfield and Raymondsville, Tex., I understand that this operation is non-Federal, is it not?

Mr. DI LUZIO. It is non-Federal to the extent that it is not being built by the Government, it is being built by Raymondsville, Tex. But it has been funded by the HHFA through a \$391,000 outright grant and a \$436,000 loan on a 40-year basis at $3\frac{7}{8}$ -percent interest rate. It has been funded really by a Government agency.

Mr. ASPINALL. For the benefit of the chairman of the full committee, this would have been one of the demonstration plants in 1961, or are you aware of that?

Mr. DI LUZIO. No, I am not. But I think that they have obtained this plant through their own initiative. The only point I was hoping to make was that in a situation where a Federal agency is funding a plant or is participating in the funding of a plant, that we should be able to work out some arrangement to get operating data from it. That is the only point that I was trying to make.

Mr. ASPINALL. I am in favor of that. But I just want you to know that this is one of the things that held up thought of consideration of the bill in 1961. And it seems to me that they have done pretty well. They have worked out of it without getting subsidized water from the Federal Government.

Mr. DI LUZIO. It has been subsidized to some extent, Mr. Chairman, by the outright grant.

Mr. ROGERS. What is the total cost?

Mr. DI LUZIO. \$827,000. This includes the distribution system storage reservoirs, and the desalting plant.

Mr. ROGERS. And you have got 400-and-some-thousand dollars—

Mr. DI LUZIO. On a long-term loan and an outright grant.

Mr. ASPINALL. From what agency?

Mr. DI LUZIO. The HHFA.

Mr. ROGERS. It sounds like a pretty good subsidy.

Mr. DI LUZIO. Yes; and the only point that I was making was that we would have been very happy to have participated in these arrangements because we would like to get operating data from the plant. This is a very difficult water, it has iron and manganese in it which must be removed. HHFA consulted with us as to which process they ought to use, but we don't know what technology will "spin off" from this operation.

Mr. ROGERS. Mr. Di Luzio, at this point would not it be a good idea to have some kind of a coordinated committee among the different

agencies addressing themselves to these problems associated to prevent duplication, because you are going to be paying some contractor some money for the same thing he has been paid for by the HEW or by the HHFA?

Mr. DI LUZIO. We are working on that now. There is a coordinating committee. But it takes more than just a committee to make it work. It takes a real willingness on the part of the agencies to participate.

Mr. ASPINALL. Mr. Chairman, I want to get the facts of the situation, and I want Mr. Di Luzio to answer that question.

There are 1,540 current contracts involving water research in the Federal Government.

Mr. DI LUZIO. Yes, sir; that is the total number of all Government contracts on water resources research.

Mr. ASPINALL. If the public really understood that, Mr. Di Luzio, I am afraid that some of the glamour would be taken off of the water operation.

Mr. DI LUZIO. I am very cognizant of that. And this is one of the things, as I mentioned before, that makes it necessary to have more than a committee for this work. It takes the willingness of the agencies to really participate. And it must be at a working level, not a high-level committee.

Mr. ROGERS. It sounds to me like the strong arm of Congress could help a lot.

Mr. DI LUZIO. Yes. I have seen it work quite effectively in other areas.

It is wrong to have these agencies all running on their own without checking with each other. Every time we hear of a program for which we may have something to offer, we offer it, we just don't wait until they ask us. Sometimes they don't like it, but we just want to put them on notice that they have been looking at the same kind of a problem; if they want the data on this we will make the reports available to them. We go out of our way to inform HEW or anyone else in the water business about our program. We would like to have them do the same with us, if they see us doing anything that they have already done, we hope they tell us.

It is almost a futile job to keep track of everything that is going on in the various agencies, but I think that we are coming closer and closer together. The answer, in my mind, is not a high-level cabinet or a subcabinet level committee, but rather a working-level committee that really knows the details of what is going on.

Mr. ROGERS. What I have in mind is, is a committee authorized to coordinate these efforts with strict requirement in law that all information be provided to that committee, so that you won't have to chase around from one agency to the next, that you can get all this from one committee, and anyone from the outside can get it from the committee?

Mr. DI LUZIO. Well, coordination is a real problem, as you mentioned.

Now, among the other things that we are looking at very carefully is the kind of water that the various types of customers really need. Everyone seems to imply that water is water. This just is not so. There are certain kinds of customers that need pure water, there are certain kinds of customers that need water which has only 200 to 300

dissolved parts of salt per million parts of water. Agricultural water, for certain kinds of crops, can range up to 700 or 800 parts of salt, but there are some crops that cannot survive on that type of water.

One of the things we are looking at is the possibility of blending distilled water with equal parts, or some other ratio, with brackish water and come up with a water that meets health requirements of not more than 500 parts of salt per million parts of water.

The economics of the end product water is affected by the blending ratios that are used, and in many cases it is not the cost of the desalted water that is the critical factor; it is the cost of the blended water, which could be a much lower figure. This point was not made during the earlier discussion on building large plants. Large plants have specific applications. And one of the best applications I foresee is a blending factor, where one can take water which is slightly sub-standard, like the Colorado River water, which is now 700, if I remember the correct figure—

Mr. ASPINALL. Whereabouts?

Mr. DI LUZIO. I understand in southern California it is reaching somewhere between 700 and 800.

Mr. ASPINALL. I did not want you to get too far upstream.

Mr. DI LUZIO. No, the water in the Colorado River upstream is extremely good water, I have fished it many times.

Now, referring to chart D, which I think very well illustrates the kind of factors one must evaluate when talking about siting a plant, we think that the siting of a desalting plant, large or small, is a very, very complex thing. It cannot be done by the Atomic Energy Commission, or by OSW; it must be done in concert with a lot of people. The chart lists the factors that must be considered including the type of feed water, the need for water and the time period; the quantity and quality of the water requirements and the demand schedule. We must know the power needs, if it is a dual-purpose plant, and at what rate the power demand will grow. We need to know what alternative sources of fresh water are available, and the water storage and distribution capacity.

These are all the steps that one must go through to decide the siting of a large plant. Only when these things have been evaluated can we decide whether a desalting plant in a particular region makes sense or not. I just cannot pull a name out of the air and say this is a place where we would like to put a 300 million gallon plant. It is much more difficult; and it goes to the point that Congressman Aspinall raised this morning. We should not be in competition with alternative sources.

While we keep using the words "compete with," we are not in competition with other sources. Desalted water should be considered only when it provides an economical answer to a water problem either in terms of quality or in terms of quantity at a given location or for other reasons. We are not competing with other methods of providing fresh water. We will never compete on that basis, because there is nothing cheaper than natural fresh water which may be available anywhere near the consumers. No one can beat that arrangement.

We are talking about incremental water that cannot be supplied by other methods. When we look at the problem we must also look at the reclamation of waste water. This is the treatment of sewage

water for specialized purposes. That must be considered, because it is impractical to talk about a 300 million gallon plant in Los Angeles and then throw 250 million gallons of sewage into the ocean when we might be able to reclaim at least part of this water for special uses at a price which is less than we can desalt sea water in a dual-purpose plant.

Up and down the coast of California right now they are pumping Colorado River water back into wells to provide a hydraulic head to stop salt water incursion into the ground waters. There are also plans afoot in California to treat sewage with secondary treatment or tertiary treatment and use the reclaimed sewage to act as a curtain to stop salt water incursions.

These are all things that have to be looked at when we consider a regional plant. It is the only way to approach the use of desalting equipment in large sizes. I do not think this is similar to a problem of a community of 15-, 25- or 50-thousand population that needs a small brackish water plant; these would be small individual plants that can be located much more efficiently, because it is easier to transmit power from a central location than it is to transmit the fresh water. There are places where a large plant will fit, but it must fit a regional scheme such as I have talked about.

Referring to the statement that Congressman Aspinall made this morning about making the desert bloom, I could not agree with him more. I think we are a long way from making the desert bloom, in fact some people think we are a long way from making anything bloom. I would disagree with that. I think we can.

Chart E gives the timetables we set for ourselves as targets, starting in 1952 with a \$5 per thousand gallons product, and that was for the specific purpose of supplying remote small communities, islands, and tourists, through plants of approximately 0.2 million gallons a day. In 1964, through the San Diego operation we achieved \$1 water. This can be reasonable for isolated small communities in an industrial economy. In the period from 1968 to 1972 we think we can achieve 50 cents or less per thousand gallons with small plants, and definitely 30- to 35-cent water in dual-purpose plants in that time frame.

In 1970 to 1975 time period envisions a plant like the MWD, or the Israeli plant. The best estimate we have is 34 cents a thousand gallons. Beyond 1975—and I don't know how far beyond 1975—we may come up with answers, because of our basic research program, to produce 12-cent water for high-value crops or perhaps 6-cent water for low-value crops. I can't tell you how we would do that. That is why I say sometime beyond 1975, through our research programs we might uncover something we haven't seen yet, which might give us a way to do it. We might be able to do it in a combination of ways. Maybe the blending factor might affect high-priced crops such as avocados. When I was in San Diego recently, one of the things that shook me up was the effect of boron in the San Diego water on the avocado crops. The water contains only a fraction of one part per million of boron but it is adversely affecting this high-value crop. I don't know what would happen if we could dilute that water with even 30-cent water on a ratio of 4 to 1—4 parts Colorado River water and 1 part distilled water. This might be sufficient to lower the boron content enough to save the avocado crops in the San Diego area.

This is a kind of specialized application that might come into the act.

I think it is very critical to maintain a balanced program. We don't want a program that is solely geared to large plants and sacrifice small plants. This is something that I don't think we want to do or that we should do.

On chart C we start with the San Diego plant of 1 million gallons. That is the technology that we had as of 1961. We want to lead into a 1 to 2 million gallons advanced technology plant in the 1965 to 1966 time frame, followed by the 17 million gallon test module, which in turn will lead to the 50 million or even to the 150 million gallon plant in the 1972 time frame.

You will note that this is not the only program we plan. We have two other legs of the same program. We would like to proceed from the advanced technology demonstration plant to a 3- to 5-million-gallon dual-purpose plant using fossil fuels or existing heat sources.

We would like to move into the 10- to 20-million-gallon-per-day size for the dual-purpose plant for fossil fuel heat sources because they are too small for reactors. We want to get into the 50-million-gallon, dual-purpose plant, which is probably the smallest size for a dual-purpose plant using a nuclear reactor. We don't think dual-purpose plants are the answer to everyone's problem.

Mr. ROGERS. Mr. Di Luzio, what would be the approximate cost of the 3 to 5 million gallons?

Mr. DI LUZIO. The last figures I saw were somewhere between 50 and 70 cents.

Mr. ROGERS. I mean the cost of the plant.

Mr. DI LUZIO. The capital cost would run about \$3 to \$5 million, about a dollar per daily installed gallon.

Mr. ROGERS. And then the 10 to 20 million?

Mr. DI LUZIO. That cost would come down to 40 to 45 cents.

Mr. ROGERS. And then your 60 million?

Mr. DI LUZIO. Our studies show 35 to 40 cents.

Mr. ASPINALL. Mr. Chairman, I would like to go a little bit further.

At today's prices, for the program you have contemplated on that chart, what is the ultimate cost to the taxpayers of the United States in 1975?

Mr. DI LUZIO. With the total program?

Mr. ASPINALL. That is what I am talking about. That is what you are showing.

Mr. DI LUZIO. I think, in order to do this program, and do this also not only in the distillation line of plants also the membrane plants and the other processes, the figure we are talking about between now and 1972 is \$200 million. We were talking only about the development of these plants. We do not plan to cover the total cost of construction.

Mr. ASPINALL. As you come down to 1975 on that chart?

Mr. DI LUZIO. 1972 is the end of the present authority we are requesting. The chart merely reflects the evolution of the technology. Mr. Chairman, it is not intended to reflect the economics beyond 1972.

The program we show from now to 1972, reflects what we think is possible with the time and the money which we are asking for in the extension.

Mr. ASPINALL. Let me ask you this question. As a member of the Government at the present time, if you don't find the answers by 1972, would you be willing to advise us to forget the whole thing, or would you suggest that we continue on?

Mr. DI LUZIO. I think the entire program from now to 1972, including the basic technology which led to the 150-million-gallon plant will be achievable within the framework of the technology as we now see it. We are not looking for any miracle or any scientific breakthroughs to do these things. This is just a hardheaded engineering job. We are not waiting for a new invention or a miracle.

Mr. ASPINALL. The 25 cents per thousand gallon water?

Mr. DI LUZIO. This is a function of a dual-purpose plant which was the result of studies made by four or five companies which we will submit for the record if you would like. They are available, and they are the best engineering talent that we can mobilize for these protections. They are forecasts that have been made in terms of certain sizes of reactors and certain sizes of plants.

Mr. ROGERS. Would you furnish this for the subcommittee?

Mr. DI LUZIO. Yes.

Mr. ROGERS. It will be made a part of the files, subject to being made part of the record.

(The material referred to follows:)

List of reports and studies prepared by Office of Saline Water on single-purpose or dual-purpose plants

Title	Single purpose	Dual purpose
1. Report: "50 Million Gallons Per Day Plant Conceptual Design Study"—the Fluor Corp. Ltd., March 1965.		X
2. Report on "Desalting Power and Land Reclamation in the United Arab Republic," U.S. Department of the Interior and Atomic Energy Commission, February 1965.		X
3. "1 Million Gallons Per Day Plant Conceptual Design for Point Loma San Diego, Calif."—the Fluor Corp. Ltd., January 1965.	X	
4. Report of the "United States-Israel Desalting and Power Team" October 1964.		X
5. Office of Saline Water R. & D. Report No. 116, "Cost Studies of Large Multistage Flash Saline Water Conversion Plants"—Bechtel Corp., October 1964.	X	X
6. A study of "Desalting Plants (15-150 Million Gallons Per Day) and Nuclear Powerplants (200-1,500 megawatts-thermal) for Combined Water and Power Production," Joint Report, Department of the Interior, under Contract No. 14-01-0001-367 and Atomic Commission Contract No. AT(30-1)3316—Catalytic Construction Co. and Nuclear Utility Services Inc., September 1964.		X
7. Report to Office of Saline Water, "An Engineering Evaluation of the Long-tube, Vertical, Falling-film Distillation Process"—The Dow Chemical Co., July 1964.	X	
8. Preliminary Appraisal report on a "Combination Sea Water Desalting and Electric Powerplant for Jidd, Saudi Arabia," June 1964.		X
9. Engineering study of "Municipal and Industrial Water Supply for the Florida Keys," prepared at the request of Florida Keys Aqueduct Commission under Contract No. 14-01-0001-337—Burns & Roe, Inc., and Reynolds, Smith & Hills, February 1964.		X
10. Memorandum report—"Combination Electric Power and Sea Water Desalting Plants in Arid Low Cost Fuel Areas," Department of the Interior Report, August 1963.		X
11. Preliminary appraisal report on "A Sea Water Desalting Plant To Supply Fresh Water for Tijuana, Baja California, Mexico," December 1963.		X
12. A study of the "Application of Nuclear Energy to Saline Water Conversion," Office of Saline Water, November 1963.		X
13. Report of the Atomic Energy Commission, Department of the Interior, and Federal Power Commission, Interagency Subcommittee to Office of Science and Technology Task Group, "Investigating Large Nuclear Fired Saline Water Distillation Plants—For Official Use Only"—November 1963.		X
14. Parametric cost studies pertaining to "Dual-Purpose Power and Water Desalination Plants," under contract No. 14-01-0001-345—Burns & Roe, Inc., October 1963.		X
15. Preliminary appraisal report on a "Municipal and Industrial Water Supply for the Florida Keys," Office of Saline Water Report, May 1963.		X
16. Office of Saline Water R. & D. Report No. 72, "A Study of Large-Size Saline Water Conversion Plants," Bechtel Corp., March 1963.	X	
17. Office of Saline Water R. & D. Report No. 34, "Preliminary Design Study of an Optimum Nuclear Reactor-Saline Water Evaporator Process"—The Fluor Corp., Ltd., August 1959.		X

Water costs from various OSW studies

1 MILLION GALLONS PER DAY

Contractor	Year	Report number	Steam, dollars per million B.t.u.	Product water, dollars per 1,000 gallons
Bechtel.....	1963.....	72	0.37	1.30
Dodge.....	1960.....	21	1.25	1.04
Fluor.....	1960.....	34	1.35	1.11
Burns & Roe.....	1964.....	109	-----	-----

10 MILLION GALLONS PER DAY

Bechtel.....	1963.....	72	0.32	0.70
Burns & Roe.....	1964.....	109	.55	.77
Dodge.....	1960.....	21	1.25	.68-.86
Ferguson.....	1961.....	96	.25	.76-.85

50 MILLION GALLONS PER DAY

Bechtel.....	1964.....	116	0.20	0.43
Fluor.....	1960.....	34	.37	.41-.71
Do.....	1965.....	-----	.31	.35
Catalytic.....	1964.....	124	-----	-----
Burns & Roe.....	1964.....	109	.26	.48

150 MILLION GALLONS PER DAY

Bechtel.....	1964.....	116	0.15-0.25	0.31-0.38
Catalytic.....	1964.....	124	.26-.49	.31-.62
Fluor.....	1965.....	(2)	.25	.35

¹ Fuel costs.² From the Fluor Corp. statement to the U.S. Senate and House Committees on Interior and Insular Affairs.

Mr. DI LUZIO. One point that I hope I made quite clear, is the fact that we are not proposing to build these plants ourselves. We are talking about the development of the technology to do these things, and we have enough confidence in the need for plants of this size that we will always find a sponsor such as the 50 or 100 million gallon plant MWD is now considering.

I am not overly fascinated by large plants; I am more concerned about efficient small plants. I think the smaller plants will really pay off. We would not build a plant merely to prove quantity production of water, because our goal is cost rather than size.

Mr. ROGERS. Do I understand, Mr. Di Luzio, that you mean to tell the subcommittee that the \$200 million of money that is going to be used to build these plants—that some of these plants are going to be built by private corporations?

Mr. DI LUZIO. Yes.

Mr. ROGERS. What is \$200 million going to be spent for?

Mr. DI LUZIO. It will be spent on the prototype for the 17 million test module, for the prototype module for the 3 to 5 million dual-purpose plant, for the test module of the 3 to 5 million single-purpose plant, and the associated technology we will need. We would not propose to build an operating 50-million-gallon plant with present concepts. We will lead up to it by building these smaller versions.

Mr. ROGERS. What I understand is that when we are talking about

a 3- to 5-million-gallon plant, are those to be built out of the \$200 million?

Mr. DI LUZIO. Yes.

Mr. ROGERS. Yes.

Mr. ASPINALL. Which plant is it you are talking about that private enterprise is going to build?

Mr. DI LUZIO. Possibly the 150 million, but definitely the 40-, 50-, and 60-million-gallon plants. Those will be the end result of a lot of technology developed with smaller plants to meet an actual need. And as I said before, the plants would have to meet three conditions: One, they must meet a need. Two, they must be sponsored by someone other than OSW. And three, they must provide not only the high quantities of water we are shooting for, but also produce water at a certain cost range.

Mr. ROGERS. Mr. Di Luzio, let me ask you this: Do you take the position that you now have the authority to proceed in this manner insofar as getting these plants built?

Mr. DI LUZIO. No, sir; we do not have the authority; we would have to come back to Congress in each and every case.

Mr. ROGERS. On the contracting with authority groups?

Mr. DI LUZIO. Either in contracting with public or private groups, or the actual building of any plant in an operating sense, except for the module which is authorized under the proposed language of the new law.

Mr. ROGERS. Now, if you couldn't get a private group to do that, you would have to anticipate if you carried this program on out to come back to Congress to get additional money to build these plants by the Government, would you not?

Mr. DI LUZIO. We may have to, sir.

Mr. ROGERS. That is, if the private corporations wouldn't go into this?

Mr. DI LUZIO. If the technology is needed badly and we could make a case that will improve the art, and by doing it make something worth while for a future need, we may then have a case to come back and place it before the Congress.

Mr. ROGERS. Then you would be faced with the proposition, if you couldn't get the private corporation to do it, of coming back and telling Congress that they didn't know what they were doing, that you could do this and get the additional money to go ahead and build the 50 to 60 and the 150 million.

Mr. DI LUZIO. Congressman, I would have to answer it this way, that an actual need for water which the community may face—let's take the Key West situation as an example. Key West had an actual need for a certain number of gallons of water per day, and they wanted a plant which would produce this water every day, because they need it badly every day and they would consume the total production every 24 hours. If they came to us and wanted to participate in a plant which would provide that firm source of water supply, we would have absolutely no reason for joining with them, because we could learn very little from it. Their need is a well-proven process, reliable process. Our program is to advance technology. If they could get by with a 70-percent load factor so that we could experiment 3 days out of every 10, then we would be interested in participating in a joint endeavor.

So what it amounts to is that if they want something routine we would be unable to participate. If they wanted a plant which would advance the state of the art, and we had a process ready for plant programming, either through a module or an operating plant, then we would probably participate with them. It just depends on what we would buy with our contribution. It would have to be technology everytime. We would not be in the business of just providing waterplants for communities.

Mr. ASPINALL. Mr. Chairman, I did not quite understand the size of the plants.

How large and expensive can a module or a component unit be? You would not have to come back to get additional authority to build one of those, would you?

Mr. DI LUZIO. Congressman, no, because the module is not an operating plant, it would be designed as a test vehicle to prove out a concept before committing it to the design of a large plant. The largest module we have in mind now is 17 million gallons in terms of a hydraulic system, it would cost somewhere between \$7 and \$7.5 million.

Mr. ASPINALL. And you would not have to come back if you get the legislation, you would not have to ask for additional legislation?

Mr. DI LUZIO. That is right.

Mr. ASPINALL. And if you want to think in terms of 200 million gallons per day, and you determine that the module or component was 50 million, you would not have to come back for that, would you?

Mr. DI LUZIO. The only limitation—the controlling factor there would be, at least as far as I am concerned, that we would not want to take money away from other programs to do that. We would try and test a module design with the smallest possible size for the least amount of dollars. A 50 million gallon module would force us to take money from some other programs to do it. I keep repeating that I am going to keep a balanced program. I am not going to let any piece of the program which is important suffer because of some dramatic thing that some one may think we want to do.

Mr. ASPINALL. You would not object too much if we wrote a very good report on this particular authority, would you?

Mr. DI LUZIO. I am sorry, sir, I do not know what your definition of a good report is.

Mr. ASPINALL. That is, require you to keep us informed all the time so that we can stop you.

Mr. DI LUZIO. I agree that we ought to keep the committee informed. We need to be forced once in a while to defend our program. We do not have all the wisdom in the world, and we can make mistakes like anyone else in the world.

But the trouble is——

Mr. ASPINALL. You have got all the scientists, we do not have any.

Mr. DI LUZIO. But once in a while the scientists go off the deep end too. And my problem with scientists is to know when to take things away from them.

Mr. ROGERS. Mr. Di Luzio, in order to be able to write the report, you say you did not know the definition of a good report, do you not think it would be nice if you gave us the definition of a module?

Mr. DI LUZIO. A module is a segment of a large plant which will test out the hydraulics of a system or the arrangement of the evaporator trays. When we design a 17 million gallon module to test the hydraulic system we pump water through it in a manner that will stimulate a 17 million gallon plant, but we may have evaporator capacity to produce only 2 or 3 million gallons of water. We would use only a single bank of evaporators to get the performance data we need.

We face many real engineering problems. Should we, or could we build a single 50-million-gallon plant as one unit with one pumping system, or should we build one plant with two pumping systems to get better hydraulic efficiency? Perhaps our tests will show that it is best to build a plant with three 17½-million-gallon hydraulic systems. We can obviously build a 50-million-gallon plant by putting fifty 1-million-gallon plants side by side. This would be stupid, because we would not gain anything by doing this. By designing larger components we can double the capacity of a plant, but not the cost. We can do it for maybe less than two-thirds of the cost. This is the benefit of scaling up. This is where we gain by scaling up, and to learn how to do this we need to build some modules, models, and components.

Mr. ROGERS. What do you mean by a component?

Mr. DI LUZIO. A component, for example, is a feed pump, a deaerator which removes the air from the water, or a heat exchanger. These are the components I am talking about, big pieces of hardware that perform a specific function.

Mr. ROGERS. Now, the point is simply this, that I was wondering why you felt it necessary to put these two words in after "laboratory," before "powerplant." Isn't that where you have inserted them?

Mr. DI LUZIO. Yes.

Mr. ROGERS. In section 2(b) it reads: "The Secretary of the Interior shall conduct the engineering research and technical development work to determine whether laboratory"—and then you want to insert the words "module and components?"

Mr. DI LUZIO. Yes.

Mr. ROGERS. And the sentence would then continue under present law "and pilot plant testing."

I was just wondering, you felt, I am sure, the Department felt that a module and component, as you have described it, was not included so far as your authorization here is concerned.

Mr. DI LUZIO. That is right, sir.

Mr. ROGERS. And, of course, it is supposed to mean demonstration plants.

Mr. DI LUZIO. That is also right in the sense that a module is a scale-up of a laboratory device, or a pilot plant which has been testing a process—the general development of a process in our program runs something like this. We do a conceptual study followed perhaps by a laboratory model. If this works well we may then go into a pilot plant operation. A pilot plant is an engineering development facility, perhaps it can be described as a "hardware test tube." The data they provide is more important than the water they produce. By an agreement with this committee they are limited in size to 75,000 gallons per day. This is the kind of thing we build at Wrightsville Beach for a

few thousand dollars. We propose to build models and modules on the west coast.

We have no further authority under the demonstration plant act, nor do I think we can really make a case at this time to build that kind of a plant. In fact, I don't like the word "demonstration." I like "prototype." We feel that it is necessary to request this module authority to build some large-size equipment without having to build a complete system. Through these modules we will gain enough engineering information to be able to develop the design of the large plant. The module is simply a test vehicle, it cannot be used as an operating plant.

Mr. ROGERS. Do you mean that module and prototype would be synonymous?

Mr. DI LUZIO. No, sir. A prototype is an actual full scale operating plant built to respond to a need for water and at the same time advance technology. This is one which a community would sponsor.

Mr. ROGERS. Module could, then be synonymous with mock-up?

Mr. DI LUZIO. That is right.

Mr. ROGERS. In the airplane business, I guess.

Mr. DI LUZIO. It would not be operated to produce water consistently; that is, it is an experimental facility that can be operating one day and down the next. It would not be designed as an operating plant.

Mr. ROGERS. Had you finished with your statement, Mr. Di Luzio?

Mr. DI LUZIO. Yes, sir.

Mr. ROGERS. We will move on to the questioning.

And as chairman of the full committee, we will recognize Mr. Aspinall for questions.

Mr. ASPINALL. Mr. Di Luzio, you were not the Director when this program was studied and advanced in the first place. Do you now accept the proposal as being your own?

Mr. DI LUZIO. Congressman, as I understand your question, whether or not I accept the program as it had been formulated prior to my joining the Office of Saline Water, yes, sir, I do. It is the administration's program. I, perhaps, will improve it slightly, also perhaps pace it differently.

Mr. ASPINALL. You referred to some Committees that helped you. Are the Committee members paid per diem and travel expenses, the Committee for Evaluation of the Freezing Process, Research Review Board, and the Committee for Evaluation of the Distillation Process, and the Committee for Evaluation of Reverse Osmosis?

Mr. DI LUZIO. Yes, sir.

Mr. ASPINALL. There is no limitation on the number of committees that you might have, is that correct?

Mr. DI LUZIO. Yes, there is.

Mr. ASPINALL. How is that?

Mr. DI LUZIO. We only have certain areas where we are interested in using committees. They are not continuing committees, they are set up specifically to do certain things.

Mr. ASPINALL. You suggested that you were having a meeting this fall of some of the scientists of the world who are interested in this field of operations. The companies which these men represent, will

they pay the expenses, traveling expenses and housing for these visitors to this symposium?

Mr. DI LUZIO. I think there are only one or two cases where the State Department felt that we should pay the expenses of the participants. The vast majority of them will be paid by their own countries.

Mr. ASPINALL. Is there any secret as to what those two or three countries are?

Mr. DI LUZIO. We can give you the list of the names and the countries they represent.

Mr. ASPINALL. I would ask that that information be placed in the record at this point, Mr. Chairman.

Mr. ROGERS. Without objection it will be so ordered.

(The information referred to follows:)

All official government delegations which have been designated to participate will attend the symposium at the expense of their government. Approximately 100 technical papers will be presented in this important meeting and of the foreign nationals invited to present papers, all but one will pay their own expenses. The single exception is Dr. B. A. Cooke of the Imperial Chemical Industries Ltd., London, England, who will present a paper on "Phenomena Associated with Concentration Polarization in Electrodialysis."

In addition to Dr. Cooke's expenses, we are also cooperating with the Natural Resources Development Group of the United Nations on a seminar they have established which will immediately precede the international symposium on water desalination. The U.N. is sponsoring the attendance of carefully selected personnel from various water-short nations to study the economic aspects of desalting water. The U.N. will pay the transportation and per diem of about 20 to 30 conferees from their individual countries to New York to participate in this seminar. The U.N. will also pay their return transportation cost. We have agreed to pay the cost of transportation for this selected group of specialists from New York and per diem while they are in Washington, and the cost of their return trip to New York, in order that they may take advantage of the proceedings of our symposium on water desalination.

Mr. ASPINALL. From some statement that you made in your presentation, Mr. Director, I got the impression that there was some information that the Office of Saline Water had that those who were engaged in the private enterprise operations in the same field did not have. Is that true, or are those who are engaged as private enterprises in this respect receiving the information which is at your disposal?

Mr. DI LUZIO. We pass out information on all of our experiments and the results thereof to everyone engaged in the program. We have a very wide distribution of technical information. This is one of our most important roles, to really place industry in a competitive position by keeping them currently informed of developments.

Mr. ASPINALL. I agree with your approach. The question in my mind is whether, because of this situation, the things that you are learning are passed on, and we hope that you are learning from them also. Maybe they are a little bit closer to taking over some of these responsibilities than some of the people in the Government feel at the present time.

You don't need to answer this. This is the only reason that I asked that question.

Mr. DI LUZIO. I would like to answer if I can.

Mr. ASPINALL. Go ahead.

Mr. DI LUZIO. This has been discussed with the contractors, and the majority of the contractors feel that there is still quite a role for the Government to play. As soon as a plant can be placed into an op-

eration which proves the economics of 30- or 35-cent water, this is the time that they want to go competitive. The situation now is that there are only two competitors that I know of who feel comfortable because they have been engaged in this specific kind of a process.

I will name them if you like: Westinghouse and Fluor. These are the only two who think they are ready to go to larger sizes. The other contractors have not been as extensively exposed to the program and still lack experience.

The technology of large plants is still not developed. The question is, do we want to stop developing information and stop encouraging contractors to get into this business, so that we wind up with only two companies that can compete in these large plants?

Mr. ASPINALL. I think when we get into the work tomorrow you will find that maybe there are one or two other companies. At least one company told me.

Now, Mr. Director, in a letter of April 20 reporting to the Congress on the saline water program it was stated in connection with the conceptual design studies as follows: "Several contracts have been awarded for design studies for a 50-million-gallon-per-day plant which we have proposed to construct in southern California."

When was your proposal made, and to whom was it submitted?

Mr. DI LUZIO. We awarded 15 conceptual study contracts at \$50,000 each. These contracts will cover only a fraction of the cost. The companies will absorb the balance. These firms were selected from more than 35 companies who came in and made a proposal. Some of them were eliminated on the grounds that they had neither the capacity or the background to make a contribution. We tried to pick the best, but there are some good contractors who did not come in under this program.

Mr. ASPINALL. You do have a few people that were a little bit disgruntled that they weren't considered, is that right?

Mr. DI LUZIO. Yes, as I understand it, that is what happened, but this took place before I got there. I have talked to at least one of those contractors who is unhappy. I reviewed the basis on which the conceptual grants were made, but by then we had run out of money; we only had \$750,000 in the first place, so there wasn't much I could do about it.

Mr. ASPINALL. In statements made today it has been suggested that we have a west coast test center. Does the construction of this test center depend upon the enactment of this particular legislation, and are you able to justify the need for a test center on the east coast as well as the west coast?

Mr. DI LUZIO. Yes, sir. The location of the large plants, as we see it, will be on the west coast. We would like to put a test facility close to where these large plants will be built.

Wrightsville beach is not equipped to handle the facilities we propose for the west coast. The sea water intake is not big enough, nor is there power or steam available to support a large facility. We also believe that it would be more economical and better for the whole program to build it on the west coast.

Mr. ASPINALL. Is there any likelihood that you may decide to suspend operations at Wrightsville?

Mr. DI LUZIO. No, sir. I think Wrightsville is still serving a very useful purpose to test the pilot plants that are now operating there.

Mr. ASPINALL. Mr. Director, in connection with the construction of large plants and the development of hardware, at what point do you think the Federal Government's responsibility should end and industry should take over?

This question was asked of you in just a little bit different form a while ago. And I would like to have it put on the record, and put it clearly, as to where the Government stops and private industry takes over, because you have stated your allegiance to the proposition that the Government should not be competitive with private business.

Mr. DI LUZIO. I think I can answer that best by saying that there are customers for water in almost every price range, there are people who can afford 50-cent water, people who can afford 30-cent water, and people who can afford 20-cent water. It seems to me that if we develop a large distillation plant that can actually produce water at 30 to 35 cents, and this meets a demand such as we think exists in California at the present time, then once we build a first generation plant, or participate in a first generation plant that produces water in those economic brackets, I think that that should be the end of our participation. I think we will have done our job. Once we prove out a process and we also prove the economics of the process, then I think the American industry should pick the ball up and run with it.

Mr. ASPINALL. And they should be helping all the time when they get to that stage.

Mr. DI LUZIO. Our program depends on industry every step of the way. They are extremely helpful.

Mr. ASPINALL. Would you describe the procedure your office goes through in analysis of proposals under the program in negotiations with respect to contracts? I noted recently there are certain Washington law firms and Washington representatives of various companies that spend full time in connection with contracts under this program. Are most of the contracts cost-plus or fixed-price contracts, and if so, can the proposal cost and the attorney's fee be included?

Mr. DI LUZIO. We have carefully looked into this matter as it has been asked of us before. I know of no case where the legal fees of a contractor receiving a contract from us, which has been identified in the proposal, have been allowed. They may be there, but we haven't seen them.

Mr. ASPINALL. Keep on looking.

Mr. DI LUZIO. We certainly will.

Mr. ASPINALL. Mr. Director, at the present time are there undesirable problems in applying the patent policy set out in the basic act? Have you had any trouble since you became Director?

Mr. DI LUZIO. Yes. I have had problems with two companies—Westinghouse was one, and Ionics was the other—and we felt that they had the background patents which were valuable to them. The policy of the Department was that they must give us facts on patents if they were to participate with our work. This of course is a problem with other agencies of the Government as well. It is not a problem only with OSW. We are now facing it and discussing it with Interior patent attorneys.

Mr. ASPINALL. When you were before the committee at the beginning of the year—and you will remember we postponed your appearance so that you could get organized—your office was in the process of being reorganized. Can you give the committee a brief report of your present organization, or have you completed your organization?

Mr. DI LUZIO. We have completed the organization only in terms of how we would like to organize. I have not staffed it as completely as I would like to. I talked Dr. Hunter into joining us and I have three other people I am bringing in. We have taken all research and placed it under Dr. Gillam, and the engineering is under Dr. Hunter.

Chart A, which I submitted earlier shows the lines of responsibility from the inception of a process to the building of a plant. We are no longer split into various segments so that research people are isolated from the engineering problems or engineering is isolated from research. This is one program, and the chart shows our new organization. We are not really very substantially greater in number, but we are arrayed differently. I only have two people that I can point my finger at if things don't work right. I don't have to worry about looking at a whole group of small pockets.

Mr. ASPINALL. Have you changed the ratio of your administrative personnel as compared to the scientific personnel that you have in the organization?

Mr. DI LUZIO. Yes, I have. One of the weakest points I found in the organization was that we were busy developing technology, but not doing a job in terms of protecting the Government's money, in terms of contract administration, in terms of contract negotiation. I have increased these people.

Mr. ASPINALL. Which ones?

Mr. DI LUZIO. I will come to it in a moment.

In the administration I have added two contract people.

I have added another financial person who audits the contractor's accounts and checks their reimbursements and so forth—the processes that would use Department of Defense audit agencies to audit our contracts in their areas. But we have nobody in our office who can really consult with the Department of Defense auditing agencies as to what our principles ought to be. They would only audit an account in the manner in which the Department of Defense has been auditing it for years, but it would be up to us to allow or disallow, and we didn't have the talent in the house to look at each of these contracts and pass judgment.

So I have beefed up two areas, administration and program analysis.

Program analysis is a group which will take a look at the economics at a proposed site—economics of a proposed operation, will take a look at the cost involved, will take a look at the time involved. Thus we have taken out of the operating divisions the responsibility for making administrative judgments. They should stay in the technical field, and we should have good, sound administrators to handle the program once it goes into the contract state.

Mr. ASPINALL. Have you added to your scientific personnel since your appearance here?

Mr. DI LUZIO. Yes. I have added Dr. Hunter, who strangely enough has a Ph. D. in nuclear engineering. But his basic strength is in systems engineering and systems management.

I have added two other engineers. One is on board now, Mr. Crutchfield, who was with the Navy, and who has had quite a bit of experience in submarine and shipbuilding in component development. He is now in our program analysis group.

I have another man who is also a top engineer in the engineering analysis group who is looking at the engineering reasonableness of certain kinds of approaches we make.

Mr. ASPINALL. Turning now to the International Symposium which will be held in Washington, what will that cost the United States, and what part of the cost will come from the Office of Saline Water?

Mr. DI LUZIO. There is \$100,000 allocated for the Symposium and this includes the expenses of the few delegates I mentioned earlier.

Mr. ASPINALL. What is your policy, Mr. Director, as to permitting members of your staff to attend the growing number of international meetings as well as other meetings in this country?

And remember, while I ask that I am very sympathetic to your position, because we Congressmen are under the same thing all the time, too.

Mr. DI LUZIO. We don't do it on a quota basis, but rather on the basis of the paper the man proposes to present. If it is a worthwhile paper, if it is a worthwhile contribution to a major meeting or symposium, he will go. If not, he will not. We don't have our staff participate on a rotation basis just so that they can take vacations at our expense.

Mr. ASPINALL. And they don't interfere with the regular work in the goals of your office?

Mr. DI LUZIO. No, they must clear with their immediate superiors, which in most cases is Dr. Hunter and Dr. Gillam. I must approve all travel. They can't go anywhere without my signature.

Mr. ASPINALL. One more question. It has been brought to my attention in a letter dated May 5, 1965, signed by Mr. Gillam relating to a proposal from Mr. J. Wilbur Anderson in connection with the freezing process in which Mr. Gillam indicated that the Office of Saline Water could not support the proposal at that time. I am not asking you to comment on this at this time, but I would like to have a report indicating your dissent and your inclination not to support it.

Mr. DI LUZIO. We will do that, sir.

Mr. ASPINALL. I would ask that it be placed in the record.

Mr. ROGERS. Without objection is it so ordered.

(The information referred to follows:)

Pursuant to correspondence (exhibits enclosed) and meetings between the Office of Saline Water and Mr. J. Hilbert Anderson, consulting engineer of York, Pa., the following comments are submitted as evidence to show why Mr. Anderson's proposed method was not considered to be of sufficient relevance to the current saline water conversion program:

After more than 10 years of research and development on saline water conversion there are process areas which have advanced sufficiently so that many suggested process changes are of marginal significance and thus are not of interest to the Office of Saline Water. There is also the situation, as in the case of Mr. Anderson's proposal, where the conversion process techniques are similar to ones already being investigated. The claimed economic advantages in such new proposals are unproven, but their chance of making any significant contribution to cost reductions can be rather closely estimated by comparing them to extensive development programs which have been underway in the same process areas.

Mr. Anderson's process was considered not promising initially by the Office of Saline Water because he proposed to use propane as a refrigerant in direct contact freezing of sea water. The hydrocarbon, propane, forms a hydrate with water at a temperature not too far removed from the freezing point of sea water. Although the conditions for hydrate formation and ice formation are not exactly the same, they are sufficiently close to cause difficulty in a freezing process. The hydrate crystal is small and can be difficult to separate from the mother liquor. The washing of such crystals free of occluded brine is also a special operation. Mr. Anderson was informed of these technical facts and it was pointed out to him that while propane may be a very good refrigerant, it had the great disadvantage of forming hydrate crystals which would interfere with freezing of sea water and the subsequent melting of the washed ice.

In a letter dated May 15, Mr. Anderson replied that he concurred with the Office of Saline Water evaluation and was now taking the position that his freezing process was in effect a propane hydrate process. On this basis he was resubmitting his ideas for further consideration.

It should be noted that freezing and hydrate processes are not interchangeable. The formation and growth of hydrate and ice crystals must each be carried out under controlled conditions to obtain particle sizes which can be handled in wash-separation operations. The use of a chain belt conveyor proposed by Mr. Anderson is not suitable for handling either ice or propane hydrate crystals. This form of conveyance was previously considered by the Office of Saline Water and rejected as being technically as well as economically unsuitable for commercial operations. At present the Office of Saline Water has under development methods of separating and washing both ice and hydrate crystals. These are the wash column separators and cyclones for ice and hydrates, respectively. The cyclone separators have the capability of handling large volumes of hydrate slurry per unit volume of equipment. This has been demonstrated in small scale pilot plant operations. From the standpoint of efficiency, space utilization, and investment cost the chain belt cannot compare with cyclone separation in the hydrate process.

The other features of Mr. Anderson's process are not sufficiently different from processes which the Office of Saline Water is currently evaluating in the pilot plant to warrant the construction of another pilot plant. The pilot plants now in operation and/or currently under construction are adequate for studying both freezing and hydrate systems.

In reply to Mr. Anderson's recent request we are supplying the names of contractors working in these areas so that he might personally contact them to determine if some of his ideas might have merit and, if so, could possibly be evaluated in Office of Saline Water pilot plants.

J. HILBERT ANDERSON, CONSULTING ENGINEER,
York, Pa., May 15, 1965.

Mr. FRANK C. DI LUZIO,
Director, Office of Saline Water,
Washington, D.C.

(Attention of Dr. W. S. Gillam, Chief, Division of Research).

DEAR MR. DI LUZIO: Thank you for your letter of May 5 to Judge Liverant, copy to me.

I am glad you corrected my understanding of hydrate and ice formation. This was not previously clear to me from any of the bulletins on the subject. It was for this reason that I thought of the process primarily as a freezing process.

Since we can now consider this as a hydrate process, as you have pointed out, I would also like to point out that the fundamental concepts that I have shown you are equally applicable for the hydrate process. This simply means that the operating temperature is a little higher, with the probable result of less power requirements than I have projected.

In your study of these processes, please keep in mind these very fundamental advantages in my proposal:

1. Propane operates through entire cycle above atmospheric pressure, minimizing many leak problems.
2. Propane is about the cheapest refrigerant available.

3. Propane compressors are much smaller and cheaper than almost any other refrigerant compressor.

4. The pressure equalizing concept for initial heat exchangers permits much closer approach temperatures and much lower exchanger costs. This in turn reduces primary and secondary compressor power.

5. All of the wash columns you have shown in the literature, while requiring little wash water, do require recycle brine pumping of considerable amount. This pumping power adds directly to the secondary compressor power. The belt transport simply requires far less power. While I believe the belt transport is, therefore, preferable, most of the other parts of my basic plan are equally applicable to the wash column process.

6. Melting in a tank, whether hydrate or ice, is slow, and requires more driving temperature difference than melting on a belt, where crystals are in good contact with the condensing gas. Several degrees in driving temperature means a large percentage difference in power.

7. Direct contact condensing of propane in the final heat rejection from the secondary compressor means both a saving in power and a saving in investment cost.

While you may see no way to put all of this proposed process into a going project in the immediate future, I think it is important that you recognize the value of these individual ideas to the projects you presently have going. Surely, in your function of coordinating and guiding the whole vast job of low cost water process development, there must be some way that you can utilize any valuable idea that could contribute to the success of this whole development. As some examples of what I mean:

1. The concept of equalized pressure heat transfer applies to any freezing or hydrate process, as well as to all vaporization processes.

2. The belt and tunnel, crystal collection, drying, washing, and melting process applies to either freezing or hydrate processes.

3. The gas vortex mixing and crystal growing scheme should apply to any refrigeration crystallization process.

4. Direct contact condensing of refrigerant will reduce both investment and operating cost on any freezing or hydrate process using a refrigerant that is immiscible with water, and this would include any of the hydrocarbons.

In view of all this it would seem logical to me for you to look at your various projects, both heating and cooling, to see where some of these ideas could be applied. Then it would be logical to get me in touch with the groups directly involved, so that definite and more detailed steps can be considered.

In your function to develop a practical, low cost answer to the water problem I am sure your objective is to leave no promising ideas lying around, unused.

You state in your letter that you have studied my proposals very carefully. I take from this that this means that my performance figures stand up. You will note that these performance figures are considerably better than any shown in reports issued from the Office of Saline Water.

I sincerely believe that my processes will give the breakthrough to the objective of production of fresh water at a practicable low cost. Is there not some way that this can be explored?

Congressman Craley suggested that I keep him advised, and accordingly I am sending him a copy of this letter.

Yours respectfully,

J. HILBERT ANDERSON.

APRIL 21, 1965.

Mr. F. C. Di Luzio,

Director, Office of Saline Water, Washington, D.C.

(Attention of Mr. W. W. Rinne, Chief, Branch of Special Projects).

DEAR MR. DI LUZIO: I appreciated very much getting the 10 additional reports sent me by Dr. Gillam.

I have now studied these reports pretty carefully, and am glad to say that they have broadened my knowledge of the desalting processes considerably. They have also confirmed and strengthened my conviction that the propane freezing and belt transport scheme is sound technically, economically and practically.

In studying the reports I wanted primarily to find the possibility of propane hydrate formation in the freezing process that I have proposed. Mr. Gillam expressed some concern about this.

I immediately found that Dr. Gillam was correct, and that some hydrate should be formed, according to the phase diagram in Report No. 90, page 10. Unfortunately, the phase diagram in Report No. 90 says nothing about the relative quantities of hydrate and ice that would be formed at temperatures below the ice crystal formation temperature. I could not find this specific information in any of the reports.

Not having this direct information we must estimate the relative production of hydrate and ice from other measurements, theory, and implications.

We should expect, in the temperature and pressure region where both ice and hydrate could be formed, that the most rapid formation would occur in the state which requires least removal of heat per unit mass. Since heat of fusion of ice is 144 B.t.u. per pound whereas that of hydrate is 150 B.t.u. per pound of water we would expect a higher percentage of ice crystals than hydrate crystals to be formed.

More direct information is also to be found from Koppers data, where they tried to form hydrate by spraying liquid droplets into a propane gas atmosphere. The maximum rate of formation was 1 percent at 3°C. driving force. (No. 90, p. 90). If we expect this then in the freezing process the ratio of hydrate to ice formation would be $0.01/(0.40-0.01)$ equals 0.025.

Assuming such a rate of hydrate formation, we could melt the hydrate by two possible methods. The first is to extend the belt into a hydrate melting chamber, operating at 43F, as shown on my drawing 2-E-1.

Since the driving range of the primary compressor in my freezing scheme is 6.5F, the penalty for hydrate melting is that this range is increased to 16.5F. However, since only the hydrate crystals are transported to the higher temperature melter this is not a great penalty.

The increase in primary compressor horsepower would be approximately $0.025/(16.5-6.5)/6.5$ equals 3.84 percent. This is quite nominal.

A second method of melting the hydrate is merely to dump it into the fresh water. Since the crystals have a specific gravity of 0.88 and since they will be only 3 to 7 microns in diameter (No. 90, p. 20), they can easily be pumped through the heat exchanger with the water, where they will be melted and finally removed from the water in the direct contact propane condenser.

This second method will probably cost less for equipment, but may be slightly less efficient thermodynamically.

Some further evidence on relative formation of ice and hydrate can be gotten from crystal growth rate data.

Linear crystal growth rate of ice can be taken as 0.03 centimeters per second at 0.4°C. under cooling (No. 127, p. 32). Linear hydrate growth rate can be taken as 1.23 microns per minute (No. 90, p. 22).

The ratio of ice growth rate to hydrate growth rate is 15,000 to 1. If we accept this, then hydrate formation is insignificant in the ice freezing process.

While temperature and pressure in the washer is in the hydrate forming range, heat is not being removed, so that additional hydrate should not be formed in this part of the process.

To sum up the hydrate problem, as it applies to my proposed freezing process, we should not ignore it, but I do not believe we need expect it to be a serious problem.

In studying the reports I found various items of interest useful for comparing my proposed freezing process with the hydrate and the water vapor absorption freezing process. I am noting these various points at random, because they seem to be pertinent to an evaluation of the relative merits of the processes.

A comparison of reactor volumes for the three processes is quite enlightening. For a 10 million gallons per day plant Koppers estimates 134,000 cubic feet for the hydrate process (No. 125, p. 4). Carrier estimates 157,000 cubic feet for evaporative water freezing (No. 113, p. 51). I estimate 36,000 cubic feet for the propane freezing process. The basic reason for the smaller size is better heat transfer and higher velocities being possible in a gaseous atmosphere than in the flooded liquid process. In addition to this the driving temperature difference must be greater when evaporating gas through a liquid body. This is well known in refrigeration practice.

The Carrier process uses a large amount of auxiliary power. In fact the figure of 46.1 kilowatt-hours per 1,000 gallons is quoted (No. 113, p. 74). Note that this alone is far higher than the total power of 15.7 kilowatt-hours per 1,000 gallons required by my propane freezing process. While the power

requirements are not specified in detail, the reasons for the high power requirements of the absorption freezing are quite fundamental, and can be outlined roughly as follows:

1. With the recycle ration of about 6 to 1 (No. 113, p. 28) not only the ice must be transported from freezer to melter, but six times as much brine to go with it. In the belt process only the ice is transported.

2. The driving force for freezing must be high because of the necessary depth of liquid in the freezer. In refrigeration evaporator practice this is commonly known as the static head penalty. With water droplets in the gaseous atmosphere this penalty is eliminated, and the driving force can easily be 1° F. or less.

3. The condensing temperature must be relatively high in the absorption process because condensation is done in the absorber, with heat transfer surface between the absorber solution and the melt water. This water must in turn transfer heat to the ice to melt it. In the propane process with belt melter, heat transfer is directly from condensing propane to ice crystals, and a driving temperature of 1° or less is easily possible.

4. Multiple vessels mean higher insulation heat loss and higher pumping work between vessels.

5. The very high heat rejection requirements from the heat using absorption process make cooling water pumping powers quite high.

6. Heat rejection must be through a surface condenser, whereas we can use direct-contact condensers for the propane.

7. All high-parasitic powers add to the power required of the secondary compressor.

In the Koppers hydrate process they propose a primary compressor temperature range of $(45-35)=10$ F. (No. 90, p. 11.) I question this because I believe the driving force in a tank melter is likely to be more than 2.7 F. As contrasted to this the propane-freezing process requires a primary compressor range of 6.5 F. in the first stage and 8.0 F. in the second stage, or a rough average of 7.25 F. for both stages. This is based on 1 F driving force in freezer and melter, both conservative because of large surface area of crystals in direct contact with vapor, and no static head penalty. This means that primary compressor power will definitely be less for the freezing than for the hydrate process.

The mixing power alone in the hydrate former amounts to 9.0 kilowatt-hours per 1,000 gallons (No. 90, p. 90.) This power must be added as a refrigeration load to both primary and secondary compressors.

The pressure drop in the hydrate filter is extremely high. (No. 125, p. 19, 20.) This adds considerable pumping power, and power to secondary compressor.

Koppers tests (No. 125, p. 10) showed that polypropylene cloth is a satisfactory filter material, providing that frequent back washing is used. Note that with a moving belt backwashing is automatic, since in the washer the flow of water is reversed in the lower belt.

Since Carrier has successfully shown that wash water percentages of 5 percent are sufficient in the ice column type of washer (No. 113, p. 14, 15), it is safe to say that 5 percent will also be sufficient in the belt washer. I have conservatively estimated 10 percent in my performance estimate, but this could obviously be reduced to 5 percent.

It is not very easy to scale up the size of a wash column to large capacities (No. 113, p. 23, 24). This is not much of a problem with a belt.

Carrier has demonstrated that wash spray distribution is important, but rather easy with a moving spray header over a stationary bed (No. 113, p. 42). We can easily get the equivalent of this with stationary sprays over a moving belt.

It was pointed out in report No. 113 that control of the liquid and ice column filter washer is basically rather difficult and complicated. This problem is almost completely eliminated by mechanical ice transport with a moving belt. There is no recycle brine required to effect ice movement, and wash water control is completely independent of ice movement.

The many advantages of the propane ice freezer and belt system appear now to stand out more than ever. Knowing that you are vitally interested in making the fastest possible progress in economic water desalting, I hope that you can see fit to consider this process in more detail in the near future.

Yours respectfully,

J. HILBERT ANDERSON.

LIVERANT & STEWART,
York, Pa., April 8, 1965.

Mr. F. C. Di LUZIO,
Director, Office of Saline Water,
Washington, D.C.

DEAR MR. DI LUZIO: Thank you for the time and courtesy extended to Mr. J. Hilbert Anderson and myself on our visit to your office on March 31.

From the discussion which followed with the members of your staff I feel there is some hope that Mr. Anderson has several contributions to make on the desalinization process. I wonder if we might hear from you as to any progress in this regard.

I am sending a copy of this letter to Congressman Craley so that he will know of the courtesy and attention that we were given by your office.

Sincerely,

LIVERANT & STEWART.

DEPARTMENT OF THE INTERIOR,
OFFICE OF SALINE WATER,
Washington, D.C., May 5, 1965.

Mr. SPENCER R. LIVERANT,
Law Offices of Liverant & Stewart,
York, Pa.

DEAR MR. LIVERANT: Thank you for your letter of April 8. Because of the excellence of Mr. Anderson's presentation to this office, we have reviewed the proposed process in relation to our current program requirements with particular care. While we were very favorably impressed with Mr. Anderson's personal qualifications and record of accomplishment, we do not see any practical means of undertaking development of the process at this time.

From Mr. Anderson's letter of April 21, it is clear that we did not adequately explain the circumstances and consequence of hydrate formation. Ice, liquid propane, and hydrate do not coexist in equilibrium. Perhaps this can best be explained in conjunction with the enclosed figures. If the propane pressure is above a critical value at a given temperature, (line EB), hydrate forms instead of ice. If the propane pressure is below this critical value, ice forms. Thus it is not a matter of competitive rates, but rather an "either or" situation. The only conditions where one can form both hydrate and ice simultaneously are on the line EB.

If, however, it is desired to use propane as a refrigerant, one must operate on (or at least very close to) the condensation line. Unfortunately this means that to realize the advantages Mr. Anderson seeks—which are indeed very significant—one must operate in the hydrate regime. One has then a hydrate process rather than a freezing process, and starts engineering the process explicitly for advantages inherent to hydrate processes. While the refrigeration industry may have been very slow to adopt higher pressure refrigerants, the advantages are now well recognized, thanks largely, I am sure, to Mr. Anderson's efforts. Were it not for the fact of hydrate formation, I do not doubt that propane would be the refrigerant of choice in freezing processes today. The fact of hydrate formation does exist, however, and we believe any utilization of propane must necessarily be in a hydrate process.

The belt-transport scheme would not, in our opinion, compare favorably with the more advanced and highly efficient wash columns which have recently been developed. These require essentially no moving parts and require less than 5 percent of the product water to remove brine from the ice. Thus while belt transport might compare favorably with the wash columns of several years ago, we are unable to convince ourselves of any economic advantage relative to today's technology.

Freezing processes are presently undergoing an intensive review by a committee of experts to ascertain whether and in what way they may (or may not) contribute to achieving the goals set for this office. For this reason also, we are reluctant to make any expansion of effort in the general area of freezing until this evaluation has been completed.

We are sorry to be so discouraging, but cannot realistically be otherwise under present conditions.

Sincerely yours,

/s/ W. S. GILLAM
(For) FRANK C. DI LUZIO,
Director.

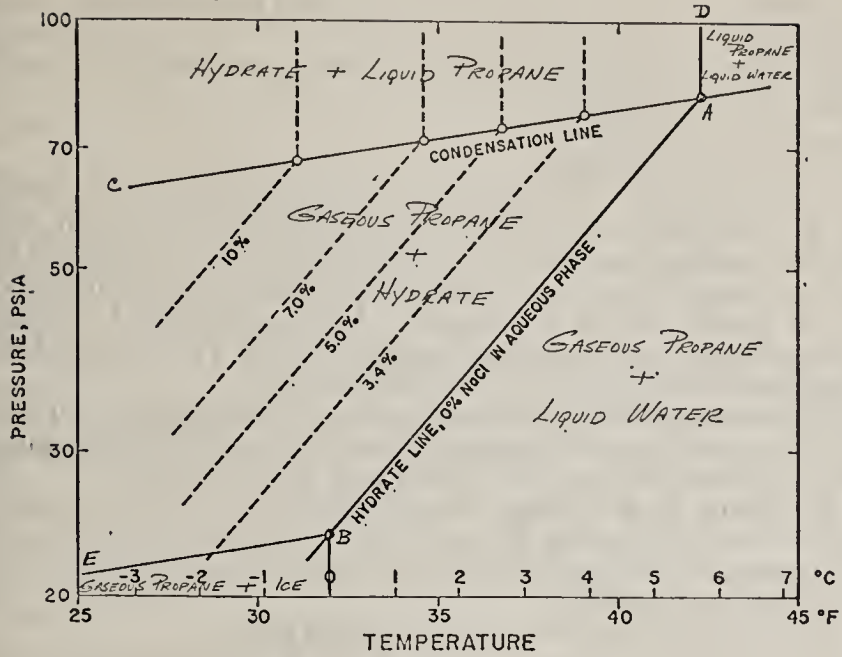
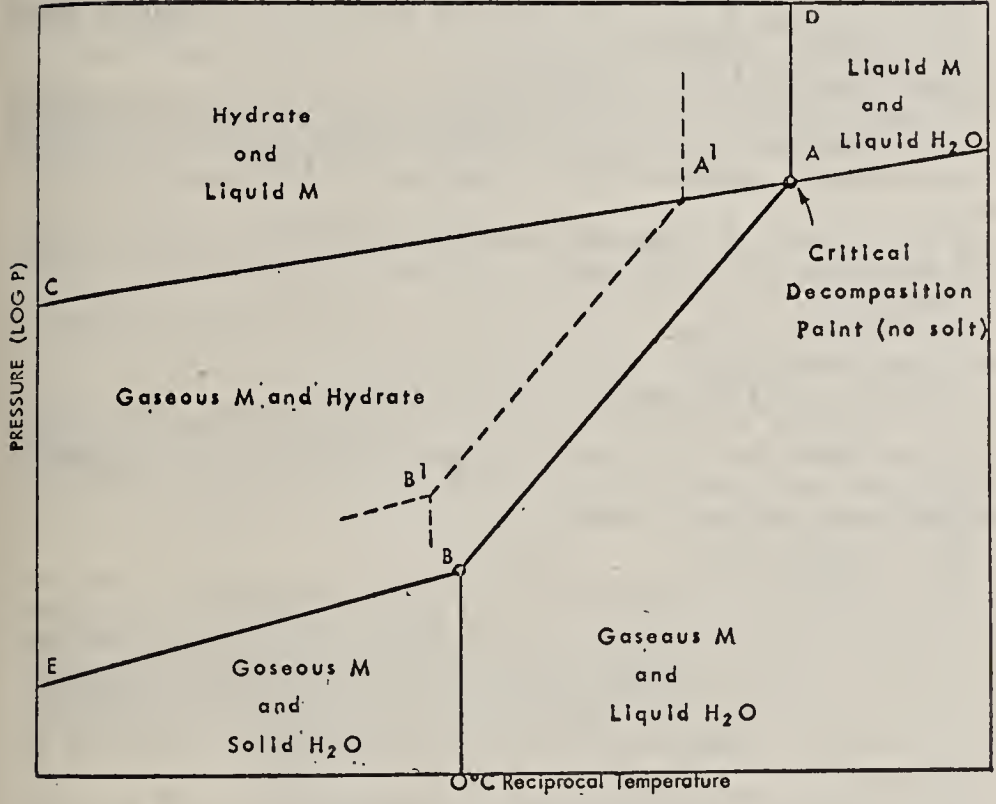


FIGURE 3
PHASE DIAGRAM FOR PROPANE HYDRATE



Mr. ASPINALL. Unless, Mr. Chairman, the Director thinks it should be considered classified material, and then we shall honor it as such.

Mr. DI LUZIO. I would hope that we don't have classified operations. I have had quite enough of that.

Mr. ASPINALL. Sometimes I know you don't like to give it out.

Mr. ROGERS. Mr. Reinecke.

Mr. REINECKE. Mr. Di Luzio, in the new Point Loma operation which you propose you have indicated that you are going to increase the efficiency of the percentage. By what factor do you intend to improve—by what factor do you intend to decrease the cost of water?

Mr. DI LUZIO. About 20 percent. And I think the best index is that the ratio of fresh water per pound of steam will increase from 10 to 20 gallons of fresh water per pound of steam.

Mr. REINECKE. And I believe you also indicated that you had—I have got it somewhere in the paper—that your cost at the present time is, what, a dollar, \$1.11 at the Point Loma I installation?

Mr. DI LUZIO. It is a dollar when we optimize the cost because the final runs were producing 25 to 40 percent above design capacity.

Mr. REINECKE. Did you actually operate at all at that level, or were those accounting figures?

Mr. SIEDER. That was the average over the year.

Mr. REINECKE. And this is based on what amortization of equipment?

Mr. SIEDER. Twenty years.

Mr. DI LUZIO. We have a standard method of computing costs which has been consistently applied.

Mr. REINECKE. I have a copy of that.

On that subject, do you know why a good many of these publications or reports of previous research programs are not available? I would like to get six or eight of these to study up, but I was only able to get two.

Mr. DI LUZIO. You are welcome to any information we develop. We do not classify any of our information. We distribute hundreds of reports.

Mr. REINECKE. These were asked from the Department, and all I got were two of them.

Mr. DI LUZIO. I will check that very quickly.

Mr. REINECKE. On your attempt to go to higher temperatures, you have indicated that that is not your goal, and that you are actually looking for the optimum situation with respect to minimizing the unavailable energy; is that right?

Mr. DI LUZIO. Yes.

Mr. REINECKE. When you make engineering designs of any of these components I am sure you start with a performance specification. And you have an idea or an anticipated performance of the particular component. Then when you put the entire system together you always have the anticipated performance of the entire system. Have you got a system on the boards that is going to come out 30 or 35 cents?

Mr. DI LUZIO. No, 30 or 35 cents is the extrapolation of the dual-purpose plant. That is the one—

Mr. REINECKE. What is the figure that you have on the board at the present time?

Mr. DI LUZIO. The one we have on the board at the present time is San Diego II. That is the only plant which has been designed and is ready to go.

Mr. REINECKE. And this will be 60-cent water?

Mr. DI LUZIO. Yes, somewhere around 60 to 80 cents.

But this again is a 1-million-gallon plant.

Mr. SIEDER. It has a rated capacity of 1.2 million gallons.

Mr. ROGERS. Would you identify that gentleman?

Mr. DI LUZIO. Mr. Everett N. Sieder.

Mr. REINECKE. Do you anticipate learning from San Diego II to cut your costs by a factor of three?

Mr. DI LUZIO. No, we expect to learn more about water treatment, higher temperature operation and materials of construction like using reinforced concrete evaporator shells.

Mr. REINECKE. You think that these efficiencies plus the scaleup is going to give you a reduction by a factor of three?

Mr. DI LUZIO. Yes, because the facts of life are that the heat source will produce lower cost steam in a large plant. A small plant uses a much higher cost steam source.

Mr. REINECKE. What do you use for your cost of steam now?

Mr. SIEDER. At the Point Loma plant the cost of steam was about 50 cents per million B.t.u.

Mr. DI LUZIO. It was 50 cents on San Diego I, it is estimated at 15 cents on the large dual-purpose plant. If we are successful in building a west coast test site at a location where there is existing heat sources, we anticipate steam prices somewhere between 25 and 30 cents per million B.t.u. So here again is a saving in actual cost of heat.

Mr. REINECKE. You mentioned 15 cents on the dual system?

Mr. DI LUZIO. Yes, sir.

Mr. REINECKE. I would like to see a breakdown on that if I could, I would like to understand how that works in conjunction with the cost of the electrical output as well, and the total investment, and the organization.

Mr. DI LUZIO. I would be very happy to. We agreed to submit for the record studies made by these various firms on dual-purpose plants, and this will be in the record.

(The information referred to follows:)

STEAM COSTS FOR M-S FLASH DISTILLATION PLANTS (STEAM DELIVERED TO BRINE HEATERS)

A. POINT LOMA PLANT (1 MILLION GALLONS PER DAY) ¹

B.t.u. input (gross) to brine heater

1. Annual fuel cost, normalized plant: \$134,200.

2. Fuel oil cost: \$2.35 per barrel at 6.3×10^6 B.t.u.-barrel.

3. B.t.u. (gross)

$$= \frac{134,200}{2.35} \times 6.3 \times 10^6$$

$$= 360,000 \times 10^6 \text{ B.t.u.}$$

¹ "A Study of Large-Size Saline Water Conservation Plants," Office of Saline Water R. & D. progress report No. 72, March 1963.

Estimated boiler plant annual cost

Fuel (37.3 cents-10 ⁶ B.t.u.)-----	\$134, 200
Labor (\$84,000 times 25 percent)-----	21, 000
Interest and amortization (\$187,500 times 7.3 percent)-----	13, 700
Taxes and insurance (\$187,500 times 2 percent)-----	3, 750
Other-----	2, 000
Total-----	176, 650
Cents per 10 ⁶ B.t.u.-----	49. 1

B. LARGE-SCALE DISTILLATION PLANT

Calculations made by the Catalytic Construction Co. for a large-scale distillation plant in its report entitled "A Study of Desalting Plants (15 to 150 Million Gallons per Day) and Nuclear Powerplants (200 to 1,500 Megawatts Thermal) for Combined Water and Power Production," OSW Progress Report No. 124, November 1964, is shown below. Steam costs delivered to the brine heater for the case shown is 14 cents per 10⁶ B.t.u.

Dual plant optimization: 80-percent load factor.

Low temperature nuclear fueled: August 27, 1964.

Steamplant output: 1,500 thermal megawatts.

Fixed charge rate: 7 percent.

Steam conditions: 650.0 psia.

494.0° F.

Feed: 362.0° F.

	<i>Million dollars</i>
Investments:	
Steamplant-----	30. 649
Powerplant-----	12. 900
Water intake and canal-----	1. 819
Indirects on above-----	10. 200
Interest on construction money-----	4. 346
Nondepreciating items-----	6. 524
Waterplant (including indirects and construction money)-----	67. 229
Total-----	133. 667

Waterplant production: 141.73 million gallons per day.

Water costs: \$0.290 per thousand gallons.

Performance ratio: 11.25 pounds water per pound steam.

	<i>Million dollars per year</i>
Operating costs:	
Fuel (\$0.135 per million British thermal units)-----	4. 851
Steam plus powerplant-----	1. 680
Waterplant-----	2. 233

	<i>Million British thermal units per hour</i>	<i>Dollars per million British thermal units</i>
Steam:		
From steamplant-----	5, 119. 14	0. 2828
To waterplant-----	4, 230. 00	
To brine heater-----	4, 090. 15	0. 1400
Power (megawatts at 4. 000 million per kilowatt-hour):		
Gross-----		251. 00
To waterplant-----		33. 83
Net salable-----		217. 17

Mr. REINECKE. On that test plant that you anticipate building, are you installing such instrumentation so that you will have complete and accurate, and you might say, surplus data for whatever parameters you are interested in reading?

Mr. DI LUZIO. Yes, sir. This is one of the reasons why an experimental plant costs more than the plant we would design for pure operating reasons.

Mr. REINECKE. And these committees that you mentioned, a comment was made to me regarding this report—and I realize that this was done before you came to the scene—that the men mentioned on page 4 of this report had never actually met at a committee, but were only contacted as individuals, they never had the opportunity of committee support. Do you intend to operate your groups as committees meeting simultaneously, or will this done by correspondence with each person?

Mr. DI LUZIO. They will have to meet—in fact we have already gone through this procedure on the freezing processes study. The committee meets for an exchange of ideas. We brief each committee on where we stand and make available to them all the reports and all the data we have so that they can start making judgments on facts instead of fancy.

Mr. REINECKE. You mentioned that these were not continuing committees. Do you mean that you would replace these men with other men?

Mr. DI LUZIO. No; I don't think we need a continuing committee to look at distillation or anything else. The only reason I have appointed these committees in the first place is because I want an evaluation by qualified people outside of the Department to second-guess my impression on where we are with desalting technology. People who have been directly involved in the work may not be able to see the woods for the trees.

Mr. REINECKE. But these men would stay on a given committee to give continuity to the thought in the whole process?

Mr. DI LUZIO. Yes, sir.

Mr. REINECKE. I think that is all, Mr. Chairman.

I would just like to comment that I think your best argument all afternoon has been your own conscientiousness and sincerity.

Mr. DI LUZIO. Thank you very much.

Mr. ROGERS. Mr. Tunney.

Mr. TUNNEY. I just have one or two very short questions, Mr. Chairman.

I would like to say that I compliment Mr. Di Luzio on giving a very explicit explanation of what is going on in the Department. I would like to ask you a question with regard to the coordination with other agencies. You said that there wasn't good coordination with other agencies. Would you like to see Congress pass any legislation which would guarantee that this coordination would be better?

Mr. DI LUZIO. I really can't answer that, Congressman, because I think it takes more than the enactment of legislation to make people work together. I think it has to be a situation where the people involved conscientiously want to cooperate. Meetings can be held, committees can be appointed, but that doesn't mean there is coordination.

Mr. TUNNEY. Is there any obligation, Mr. Director if your agency develops information, for you to pass this information on to other agencies that are involved in this study of desalting water, or any obligation on their part to pass any information that they are developing to you?

Mr. DI LUZIO. Yes.

Mr. TUNNEY. There is?

Mr. DI LUZIO. Yes.

Mr. TUNNEY. And still the coordination is poor?

Mr. DI LUZIO. The reason I say it is poor—I don't mean to imply that it is nonexistent—is because coordination, in terms of passing reports from one agency to another, is always an after the fact thing. I am more interested in participating in the decision as to courses of action. So I am always one phase behind. We should get together before the fact. If someone is going to do research in a certain area, perhaps they could expand slightly in context and add to it, and thus solve both of our problems. There is good coordination in passing information back and forth. But it is history.

Mr. ROGERS. Would the gentleman yield?

Mr. TUNNEY. Yes.

Mr. ROGERS. In the water research field this was discussed at length. And it was my understanding—and I was just talking to Mr. McFarland about it—that we undertook to cover that problem at that time. And he feels that we did cover it. He, as I understand it, is the man who would be charged with the responsibility of this.

And I think it would be well, then, Mr. Tunney, that we go into this further.

Mr. DI LUZIO. I have discussed it with Dr. Hornig, Congressman Rogers, and we both have the same feeling that coordination after the fact by exchanging reports is not enough.

Mr. ROGERS. There is an old saying down in my home State that there are more ways of killing a cat than stuffing it on butter. And I think you can add to that today and say that there are more ways of getting water desalinated than going through the Saline Water Office.

Mr. DI LUZIO. That is right; and it bothers me, because I think that we have the greatest reservoir of talent and knowledge in this business, and we should at least be consulted so that we can help.

Mr. ROGERS. Thank you.

Mr. TUNNEY. I was wondering if there are any other practical applications of technology that you are determining right now on the desalination program.

Mr. DI LUZIO. Yes, there are. The point I had before was that some of our processes are very, very attractive in terms of pollution control. Perhaps they are too early yet. Reverse osmosis, for example, will even filter out viruses from water. If HEW is really interested in reverse osmosis, we could probably slightly change our program and get some answers on polluted water. We have other processes that might help solve the acid mine water problem.

The basic water phenomenon we are looking at, the characteristics of water, has application to all kinds of things, not only desalinization, but also sewage treatment, chemical processing, and many other uses.

Mr. TUNNEY. So the money that is being spent under this program is not only being used for desalination of water, but for other purposes, and some of this money would be written off for these other purposes?

Mr. DI LUZIO. Yes, if we would decide tomorrow that if there is no future for desalting, the research we have conducted is well worth the investment we have made to develop new knowledge on the fundamental properties of water.

Mr. TUNNEY. And I should have asked the Atomic Energy Commission, but I didn't, I wasn't here at the time he concluded his testi-

mony. I should have asked him this, that is, are we divulging any discoveries or technology with respect to atomic energy to the Soviet Union, and if so, if we are, is it helping them in any way, aside from the desalinization program?

Mr. DI LUZIO. Congressman, I spent some 16 years with the Atomic Energy Commission before coming to the Office of Saline Water, so I speak with some experience on that. I don't think we tell the Russians very much, nor do we tell them very much that they don't already know, because of our wide open society and the way we publish our information. In fact, we are trying to find ways to get some information from them. That is where the rub is.

Mr. TUNNEY. Thank you.

Mr. ROGERS. It will take me about 2 hours to get into this, so I think I had better not start. The late hour is an imposition on everyone. And we appreciate your testimony, Mr. Di Luzio, and Dr. Hunter and Dr. Gillam. And I want to say this as far as the Chair is concerned: that we have a situation here where the people charged with the responsibility are completely dedicated in trying to solve a very difficult problem. And we hope we can work together and have a coordination not only between the Department downtown, but the Office of Saline Water and this committee. And I am sure that it will be. We may have some controversy once in a while, but I think it will serve as a program in the final analysis.

The statements and supplemental information prepared by Dr. Gillam, Dr. Hunter, Dr. Mangan, Mr. Strobel, Mr. Sieder, and Mr. Jebens will be placed in the record at this point.

(The statements referred to follow:)

STATEMENT: ENGINEERING AND DEVELOPMENT

The engineering and development functions in OSW has the responsibility to provide and demonstrate practical and economic technology for desalting water. You will very shortly be given details on the work in progress and the potential performance of the various processes. I should first like to present our objectives as we see them.

The basic objectives of OSW is to make water desalting available as an economic and reliable source of fresh water to municipalities or areas where other sources are limited or overly costly. Since we do not expect to build these plants, we have a secondary objective, which is to bring industry to the position of marketing such plants. This objective is accomplished by making available the technology developed under OSW auspices, by spreading the base of our contracts and by helping industry understand the water problem.

Water problems vary extensively for different users. Some locations have sea water—other brackish water and there are great differences in various brackish waters. Some users require hundreds of millions of gallons of water each day and others a few thousand gallons. In some situations there is also a demand for electric power while others may not be able to effectively absorb the electrical energy produced in a dual-purpose plant. In some areas energy is cheap while in others it is expensive. Some need water today—while others have time before the problem is critical.

Accordingly, you will see in our program the development of a wide variety of processes, since we know of no single process which is always "best" or even one which has such a potential for the future. Our Research Division will of course continue a broad program of basic research which may lead to the discovery of such a single "best" process but inventions cannot be scheduled and the engineering work must therefore be directed toward refining the processes we now know. The refinement of each of the various processes follows well-established engineering development procedures—i.e., study of concepts; construction, test and analysis of bench-scale equipment; incorporation of these results into larger pilot-scale equipment; and so on until large plants are achieved. New ideas are fed into the system at a point compatible with the

uncertainties involved. Furthermore, by this multiple process approach we also provide the foundation for the growth of a competitive industry with the result that the innovations and abilities of many companies will assist us in achieving our basic objectives of making desalination available as a practical source of fresh water.

Individual companies will tend to associate themselves with one or two lines of technology. Thus while some companies will undertake to exploit freezing, others will associate themselves with distillation and still others with electrodiagnosis. The various processes each have particular advantages and particular situations where they are most effective. Any individual company will of course be interested in expanding the competitive area of its chosen process. All will face competition from other sources of water. We can therefore count on industry to carry on the refinement of a process once OSW has carried its development to the point where marketable technology is available.

Considering our responsibility to the political subdivisions who will be users of these plants, we believe that marketable technology must be interpreted as technology which will permit a user to buy a plant which will operate reliably without highly skilled operators; which employs a process well suited to the particular requirement; which will produce water at the costs expected when the contract was let; and which does not require those communities which face a critical problem today to bear the full financial burden of developing the basic technology to the advantage of other communities who can wait a few years.

The present program of engineering and development reflects our best judgment on a proper balance of effort to meet the requirements for different types of plants taking into account the stage of development and demonstration of the various processes, and their ultimate potential for economic water production.

I should now like to turn to the status of the various processes.

ENGINEERING SERVICES

ENGINEERING DEVELOPMENT TEST FACILITIES

Pilot plant test facility

Present engineering development activities of the Office of Saline Water for process development are located at Wrightsville Beach, N.C., in a test facility where various new conversion processes can be operated at the pilot plant level under controlled standardized conditions.

The facility provides the Government a site for a pilot plant testing and an east coast conversion plant. This property is ideally suited for the requirement of sea water conversion applied research and engineering development activities.

There is an available source of clean sea water; the area is protected from storms; U.S. highways border the property, thus providing excellent accessibility; there are no building restrictions; and brine disposal has not been a problem. The Research and Development Test Station, including the east coast conversion plant now occupy about 13 of the 25 acres.

This site is about one-half mile from the shore. The station has nine pilot plant plots, a skimmer pond, aeration basin, and impounding basin for waste disposal, office building and laboratory, a corrosion test building, maintenance shop, garage, utility building (boiler house), and fuel storage facilities. In addition to the 9 original pilot plant plots, 2 additional plots have been constructed and a third is scheduled, providing for a total of 12 test sites, the smallest being 22 by 32 feet and the largest 102 by 32 feet. The concrete slabs are 18 inches thick, supported on wood piles and are of various sizes. All pilot plant plots are exposed except for plot No. 1, which is enclosed in a steel frame asbestos siding building and which houses a pilot plant that requires protection from the weather.

Utilities supplied to the pilot plant area are—

High pressure steam (30,000 pounds per hour total capability with space for additional 30,000 pounds per hour).

Low-pressure steam.

Compressed air.

Sea water.

Fresh water.

LP gas.

Electrical (2,000 kilovolt-ampere maximum).

Waste brine is discharged into a drainage system from all pilot plants except those in which hydrocarbons are used. Pilot plants which use hydrocarbons in the process are located in what has been designated as a hazardous area. This area is separated from the rest of the station by a 75-foot safety zone and all wastes from these plants are directed to a skimmer pond, aeration basin, and impounding basin. The wastes from both the impounding basin and the main pilot plant area are then released into Wrightsville Sound.

The sea intake pumps are located approximately one-half mile east of the test station property in Banks Channel. A concrete pier in the channel supports three 1,600-gallon-per-minute ventical turbine pumps and a control house. With all three pumps operating, approximately 7 million gallons of sea water per day can be supplied.

The Research and Development Test Station permits OSW to centralize its pilot plant operations in one location. This concentrated effort results in more effective use of manpower and funds and produces comparative information, since all experimental units and pilot plants operated under similar conditions using the same sea water.

The following pilot plants have either been erected and operated or are scheduled for construction at the test station :

- 37,000-gallon-per-day distillation thin film.
- 20,000-gallon-per-day hydrate.
- 15,000-gallon-per-day direct contact freezing.
- 10,000-gallon-per-day descaling and product recovery.
- 2,000-gallon-per-day falling film scale control.
- 200,000-gallon-per-day east coast conversion plant direct contact freezing.
- 7,000-gallon-per-day distillation thin film (marine unit).
- 10,000-gallon-per-day ash-distillation scale control.
- 60,000-gallon-per-day vacuum freezing.
- 25,000-gallon-per-day distillation flash-evaporation scale control.
- 10,000-gallon-per-day-distillation thin film (marine unit).
- 3,000-gallon-per-day distillation horizontal spray thin film.

As the overall OSW program is expanded, the pilot plant operations at this station will continue to expand.

In anticipation of additional space and facility requirements, specifications for additional facilities are being prepared. A construction contract for approximately \$200,000 is anticipated in the 1966 program. The work will include construction of a warehouse, locker facilities, and office additions, an underground drainage system, water storage, safety alarm system, paving, and miscellaneous modifications.

The Wrightsville Beach Test Station has become a most important facility in the OSW program of saline water conversion. Space is available for future expansion; however, utilities will need to be expanded to serve the additional areas.

Brackish water test facility

The OSW demonstration plant program has included two different processes on brackish water, one at Roswell, N. Mex., and one at Webster, S. Dak. In both cases, in the operation of the plants and development of the distillation and electrodialysis processes, large problem areas have developed due to the presence of certain impurities in the water. There is a definite need for specific research and engineering testing to overcome these problems. Certain of the processes, such as reverse osmosis and freezing, may be more profitably used on brackish water; however, research and engineering testing facilities are needed to effectively develop processes for this type of water.

The inland water sources contain naturally occurring impurities and, in addition, there are other mineralized or chemically charged waters from municipal or industrial sources. Impurities not present in ocean water but of significant interest are such items as silica, sulphate, sulphite, sulphide, phosphates, detergents, and other organic chemicals. There will also be certain heavy metal chemicals such as iron and copper present in some of these waters.

There is a need for a test facility to handle brackish waters in which processes up to 50,000 gallons per day can be evaluated. Such a facility would of course use natural waters obtained from wells and surface streams but would also need to have mixing facilities to prepare synthetic waters equivalent to those found throughout the arid brackish water zones of the United States.

Component test bed facility

The development of sea and brackish water conversion processes follows in a sequence of work: research, bench scale testing, pilot plant testing, and test bed development. From the pilot plant comes a process which will produce the product and much technical data for design of operating plants. Usually there are certain features of the process equipment that are not fully explored. Examples of such features may be pumps, valves, instrumentation, vessel shape and dimensions, and materials of construction.

For the most economical arrangement of equipment for any plant, each component must be designed to fit harmoniously with the others. Much of this design work can be done by competent engineers who specialize in the various unit operations involved. The testing of those components which are of a design, size, or shape not available commercially need to be tested. The construction of a component test bed facility is planned for in the 1966 budget.

It is expected that a site can be arranged for near an existing power generating station, where steam and electric power can be purchased at a favorable price and at flow rates required. Energy requirements for some of the components may be relatively high. Water, steam and electric power needs are expected to be some 5 to 10 times greater than is available at the pilot plant test facility.

The physical requirements for the test bed facility have been estimated to be—

Steam at 50 pounds per square inch gage, 600,000 pounds per hour.

Electric power: 12,000 kilowatts.

Sea water: 70,000 gallons per minute.

Waste water: 70,000 gallons per minute.

Size of site: 20 acres.

PROPOSED RESEARCH AND DEVELOPMENT PROGRAM, FISCAL YEARS 1966-72 OF THE
DEPARTMENT OF THE INTERIOR, OFFICE OF SALINE WATER

I. INTRODUCTION

Under the impetus of the Anderson-Aspinall Act, a dynamic research and development effort has been established with its objective directed toward the attainment of low cost fresh water from the sea and other saline water sources. This research program was established only after detailed and exhaustive studies were made on desalination and the water problem. (One such study was that sponsored by the National Academy of Sciences-National Research Council in 1961—NAS-NRC Publication 941). Scientific disciplines requiring research support were detailed, and gaps in our knowledge were delineated by that study. Based on those results a well-planned, balanced, research program was laid out in great detail. Results from such a young program have been excellent and an even more productive effort is anticipated under the proposed program.

The proposed research and development program has been based on: (a) the experience and knowledge attained during the past 3½ years; (b) needed new research to fill existing gaps in knowledge; (c) the requirement to develop specific data and give the maximum support feasible to distillation and membrane processes; (d) current research projects, estimated contract renewals, and research proposals in hand; (e) the need for new concepts, ideas, and inventions; and (f) the availability of highly qualified competent scientists and engineers who have been attracted to the challenging problem of desalination.

The research activity embraces not only basic and applied research but also some development. The program supports projects in most all relevant areas of science and engineering, including investigations on byproducts; and stresses publication and coordination of pertinent scientific data. A considerable effort is being devoted to a better understanding of the kinetics and mechanisms by which heat, water molecules, and ions are transported to and across boundaries so that these basic steps (which are inherent and vital to any separation process), can be made fast and efficient. Fundamental principles, new concepts and the attainment of new knowledge that is generally applicable to any process of saline water conversion are also emphasized in the program.

The basic research effort has relatively long range objectives and is the area in which the ultimate solution to the conversion problem eventually will be found.

Before detailing specifics of the proposed research program, the unique nature of the problem should be pointed out and a realistic appraisal given as to the opportunity for research and development to yield significant progress.

The problem is unique because of the value of the product. Currently a load of dirt delivered to your residence will cost about \$5 per cubic yard, or, using water volume units, about \$25 per 1,000 gallons. Our current demonstration plants produce water for about \$1 per 1,000 gallons. So if we are successful in producing water "cheap as dirt," we are not even in the ballpark in terms of achieving our objectives. Another perspective is to consider that 1,000 gallons of water is over 4 tons of product, which by current technology requires processing perhaps 10 tons of material. Processing technology today is based on a product having an economic value of at least a penny a pound. Processing techniques and equipment have evolved on this premise, or, perhaps more accurately, where this premise is not valid, processing techniques have not evolved. Product water at 100 pounds per penny is equivalent to 83 cents per 1,000 gallons, still far more than people want to pay. In desalting, it is necessary to process a ton of product, and probably twice that amount of raw materials, for a nickel, or less. This will certainly demand the highest possible degree of ingenuity and inventiveness if it is to be achieved.

Can it be achieved? Is it even realistic to hope for success? Can research lead to practical methods of desalting sea water? The answers to all of these questions it is believed are affirmative. Desalting is a particularly opportune field for research at this time for the very reason that present processes do not approach theoretical efficiency. Whereas one could, at best, hope to increase the efficiency of an electric motor by a few percent through additional research, there is very real opportunity to increase the efficiency of water desalting by a factor of 5 or more. The way to attain major improvement in product cost is by research on the principal sources of irreversibilities (inefficiencies). For most desalting processes, these irreversibilities arise largely from transport of energy or matter at phase boundaries. Nearly all of the present processes require more than 30 times the work energy needed for reversible separation. Several can use the work available from low-temperature energy, which is seldom useful for other purposes. Existing methods employ semipermeable membranes or interfaces between phases (liquid-vapor, liquid-solid, or liquid-liquid). Most of these are rapid but thermodynamically quite inefficient; reverse osmosis is efficient but slow.

Basic research will provide a better understanding of both the transport processes and the thermodynamic losses. Hence, research has an opportunity and potential of truly unusual dimensions for achieving dramatic reductions in the cost of desalting water. This research activity is centered on the structures and properties of the substances involved (such as water, aqueous solutions, hydrates, membranes), and the fundamental processes (for instance transfer of mass, momentum, heat, electricity) which may offer the possibility of separating water and ions.

II. PROPOSED PROGRAM

The proposed program will increase support in those areas of the physical sciences where research can be expected to contribute to the solution of saline water conversion problems.

The scope is necessarily broad and encompasses the following areas:

1. Structures, including the structure of liquids and solutions: of ice, hydrates, and clathrates; and within membranes and ion-exchange resins. New basic information in these areas would remove much of the empiricism that characterizes the attempts to improve existing desalination processes and to devise new ones.

2. Thermodynamic properties of binary and multicomponent aqueous solutions; of solution surfaces; scale-forming reactions and membrane processes; and of saline water, sea water, and concentrated brine, both natural and synthetic. Notably lacking at present is information at high temperatures, pressures, and concentrations.

3. Transport phenomena, properties, and theories. Especially needed is information concerning the passage of both matter and energy across phase boundaries, in and through membranes, and at electrodes. Since all separation processes, existing or to be invented, of necessity involve movement of either water or dissolved constituents, all aspects of material and energy transport are important.

4. Membranes, an essential part of several existing and proposed separation processes, are poorly understood with regard to the interrelation of methods of preparation, structure, and properties. Much of our meager knowledge con-

cerning mechanisms of transport, ionic selectivity, and salt rejection of membranes requires a much firmer theoretical basis as well as added empirical information.

5. Materials of construction for desalting plants are necessarily a major factor in determining the cost-of-product water. Cheaper and/or longer lasting metals and alloys, plastics, coatings and sealants, cements and concretes, heat-transfer media, polymers, etc., will contribute to cheaper water from present and future processes.

6. Brackish waters represent the only feasible new source of water for many arid regions of this country and the world. Unlike sea water, brackish waters differ in quality, quantity, and composition not only from place to place, but also from time to time even at a given location. The program to date has necessarily been limited to general methods with no more than cursory consideration to variations in water composition. Because brackish waters are less saline than sea water, they are economically more attractive than sea water, and the special considerations necessary for their utilization must be recognized and dealt with.

7. Biology appears as a field that, in the past, has contributed little to desalination, but one that may now provide much information useful directly in desalination, as well as in other aspects of the total water problem. Living membranes carry on desalination operations with a high degree of efficiency. A better understanding of the mechanisms of these processes has obvious connections with the design and use of inanimate analogs.

8. Unconventional desalination ideas may provide a hint as to the possible areas in which "breakthroughs" might occur. The optimum separation probably has not yet been thought of and new ideas or little understood phenomena that appear relevant to desalination will be investigated. Unconventional methods of heating in conventional distillation processes may provide the means of eliminating costly scale formation.

The above broad areas of research point out the great diversity of problems and the intertwining of causes and effects associated with saline water conversion. A general objective of the research program is to attract the best possible talent to the problems of desalting, with new ideas, new concepts, and new inventions that will indeed break the economic barrier to universally cheap, potable water. The following sections briefly outline the recommendations for research effort in fields of particular interest, promise, or relevance to the saline water conversion program.

New concepts

It is probable that the ultimate answer lies in a yet-to-be-discovered process. Present method of desalination have centered on known processes, such as distillation and freezing, which require a phase transformation of liquid water to the gaseous or solid states. To effect these phase changes requires the expenditure of energy, which energy can be partially recovered when gaseous steam condenses, or ice melts, to reform liquid water. The efficiency of this energy recovery can be increased by judicious engineering design, but this necessarily entails increased capital costs, so that present plants are optimized in terms of current technology to give minimum-cost water by making the best possible "trade off" of capital costs and energy consumption.

As the technology of these processes advance, it will be possible to effect substantial savings by operating at conditions which were previously not optimum for reasons which new developments have made invalid. The prevention of scale, or more efficient heat transfer, or heat transfer by other than metallic surfaces (e.g. liquid-liquid transfer), or elimination of corrosion, for example, could effect substantial savings in any distillation process. Efforts to achieve these goals will be intensified as the OSW program expands. Economic recovery of byproduct(s) from sea or saline waters would aid in reducing water costs, and could afford a new source of an important raw material in its own right. Methods of operation which yield a more concentrated reject stream not only increase the water yield, but also give a brine which is more attractive for recovery of byproduct mineral values. Future efforts must be directed toward creating a technology which permits higher concentration ratios, as well as the recovery of mineral values from these brines.

As we look at the future of desalination, however, it is apparent that a process which does not require a phase change will have a great inherent advantage over those processes which do (as distillation and freezing). Reverse osmosis is an example of such a process which has undergone rapid development in the OSW

program in recent years. This is the process of expressing pure water through a semipermeable membrane by application of a hydrostatic pressure to a saline solution. If the hydrostatic pressure is greater than the osmotic pressure of the solution, the net water flux will be such that pure water is obtained from the saline solution. An inherent limitation of reverse osmosis, however, is that as water flows to the membrane surface, it carries dissolved salt with it, thereby increasing the salinity of the boundary layer immediately adjacent to the interface. The boundary layer of increased salt concentration has a proportionately larger osmotic pressure. This results in a decreased water flux through the membrane at a given hydrostatic pressure. Also, as the salt flux through the membrane is proportional to the salt concentration at the membrane surface, decreased salt rejection is experienced. Overcoming this boundary layer effect, or "concentration polarization," is one of the most important problems bearing on the future of reverse osmosis.

One approach to this problem which, incidentally, has been successfully perfected by nature in life processes through millions of years of evolution, is utilization of thin channels having dimensions smaller than the boundary layer which ordinarily would be built up. The design problems of successfully applying this solution are extremely formidable, but this and other innovations (turbulence promotion, pulsing, etc.) and design concepts (vertical spiral, shell and tube, plate and frame, thin channel, etc.) must be tested, evaluated, and brought to fruition.

Recent research results have been extremely encouraging and considerable progress has been made in understanding the fundamental principles of reverse osmosis. Equations of flow have been developed, boundary layer limitations are better understood, membrane casting techniques have been improved, and theories have been advanced to explain the role of special salts in membrane fabrication. Theories have been advanced to explain mechanism of water transport and salt rejection, and some of the physical and chemical characteristics which impart unique properties to cellulose acetate membranes have been elucidated. Whereas the early membranes had a water flux of 0.2 gallons per square foot per day, membranes have been developed under the current program which have water fluxes as high as 22 gallons per square foot per day, an increase of more than a hundredfold. A pilot plant with a design capacity of 1,000 gallons per day has been fabricated and operated successfully on sea water. The research work carried on to date has answered many of the outstanding questions about the reverse osmosis process. The results to date also point out that much additional research is required with respect to membrane cost and lifetime. The problem of membrane cost has not been exposed sufficiently, data on the question of lifetime are not entirely self-consistent, and the mechanism of failure is not understood. As a result, research must continue on—

- (1) membrane lifetime and the factors affecting lifetime;
- (2) means of improving cellulose acetate membranes and means of changing the operating conditions so that the lifetimes can be extended; and
- (3) the search for alternative materials which combine suitable permeation properties with greater durability.

In addition, new research effort will be devoted to the problems of membrane production on a commercial scale. Promising leads to ways and means of developing membranes showing properties superior to cellulose acetate have been uncovered in the basic research program. A "breakthrough" in membrane technology could occur at any time and an expanded membrane research program will increase the probability of the event occurring in a shorter period of time. Since the membrane is the key to the success or failure of the reverse osmosis process, the membrane research program requires primary emphasis at the present state of reverse osmosis technology.

Looking beyond reverse osmosis, the research program must seek new methods and new concepts of separation which do not require a phase change, which do not involve boundary layer phenomena, and which separate salt from water, rather than water from salt. Electrochemical desalination is one such method, which, compared to other processes, has inherent cost and cycling advantages that are particularly pronounced with respect to brackish waters. Most desalting processes require expenditure of work (thermal cycling in distillation and freezing, mechanical work in reverse osmosis) on the total liquid volume in order to recover only a fraction of the total water. A 3,234 parts per million brackish water has one salt molecule for each 1,000 water molecules. The inherent advantages of removing the salt from the water (rather than vice versa) are obvious.

Thus far work has centered on the use of carbon electrodes for reasons of (a) economy, (b) ease of chemical modification, (c) total available surface area, and (d) the fact that it is electrically conductive. If the inherent advantages are to be realized in fact, it is apparent that an intensified effort will be necessary to increase current efficiency, increase electrode capacity for ion adsorption, increase rate of ion adsorption, etc.

The proposed research activity will encourage additional programs of an exploratory nature, placing a high premium on inventiveness, which are not subject to one or more of the inherent limitations of existing processes, and are therefore, deemed particularly apropos to the development of a technology which could result in a "breakthrough" in the economics of desalting water. These programs will seek a process which will remove salt, rather than water, from saline solutions; will operate without a phase change, in the absence of any boundary layers, and at essentially ambient temperatures and pressures. In this way the minimum thermodynamic energy requirement for separation of salt and water will be approached.

Fundamental knowledge

Specific areas to be investigated for the development of fundamental knowledge include:

1. Basic studies on the liquid state, water, and its solutions :
 - Theoretical studies on the structure of liquids.
 - Crystal structure of all forms of ice.
 - Crystal structure of hydrates and clathrate compounds.
 - Thermodynamic properties of multicomponent aqueous solutions, particularly at high temperature and high concentration.
 - Nonthermodynamic properties including viscosity, diffusion, and conductance of multicomponent aqueous solutions.
2. Transport phenomena :
 - Theory of transport processes.
 - Transport across interfaces, due to thermal, electrical, concentration, or other potentials.
 - Mass- and heat-transfer studies with saline water flow over flatplates, spheres, and cylinders.
 - Coupled fluxes in heat and mass transfer.
 - Transport related to turbulence parameters.
3. Phase transitions, vaporization, crystallization, scale corrosion :
 - Heat transfer in evaporation.
 - Condensation coefficients.
 - Crystallization-rate controlling steps.
 - Nucleation.
 - Kinetics of crystal growth.
 - The effect of saline waters on metals with respect to composition, structure, and mechanical state of the metal, temperature, composition of solution, oxygen, inhibitors, galvanic effects, and flow conditions.
4. Membranes, ion-exchange materials, and electrochemical processes :
 - Ion-exchange membranes: Interrelation of membrane preparation, structure, and properties.
 - Ionic selectivity of membranes.
 - Theoretical and experimental studies of thermodynamic properties and their correlation with irreversible phenomena.
 - Ion-exchange: Basic studies on the structure and properties of ion-exchange resins and of water within them, and also the interrelation with properties of ion-exchange membranes.
 - Use of ion-exchange materials for special desalination processes (scale prevention by removal of scale-forming elements).
 - Reverse Osmosis: Mechanism of diffusion of water and other substances in polymers. Solubility of salts in swollen polymers, and the relation of this phenomenon to salt rejection.
5. Biological and physiological salt transport processes: Biochemical studies of biological membranes and ion pumps, composite synthetic membranes, cellular basis of salt toleration, physiology, and biochemistry of salt rejection.
6. Ion-responsive electrodes: Fundamental investigations of electrode processes and materials.

Improvement of present processes

Although existing processes offer less opportunity for a "breakthrough," the opportunity for dollar savings in future plants demands a continuing program for fundamental improvements. For example, a 1-percent increase in throughput of a billion-gallon-per-day plant would represent an incremental increase of 10 million gallons per day, or approximately three times the output of the largest desalination plant in existence today. An aggressive and imaginative program to advance large-scale desalting of sea water will require increased effort in the following areas:

Thermodynamics.—Present desalination plants are designed from data based on the properties of sodium chloride solutions. These data contain errors of a magnitude that do not seriously affect the economics of operating small-scale plants, but which may be quite significant in large-scale plants. An accelerated program of basic research will increase and make available the necessary thermodynamic data of sea and brackish waters in order to arrive at optimum efficiency designs of large-scale desalting plants.

Scale.—The operation of present-day evaporators is limited to temperature ranges of 200° to 240° F. Above this temperature range, calcium sulfate precipitates on heat exchange surfaces with resulting inefficiencies at the heat exchanger interface. A more efficient evaporator design might be realized if evaporation took place at higher temperature. It is proposed to investigate the optimum temperature for evaporation and to accelerate the search for scale control methods in order that the optimum temperature of evaporation may be achieved.

Heat exchangers.—The heat exchanger problem cannot be separated from the scale control problem. It is proposed to accelerate the investigation of heat exchanger materials from the viewpoint of higher heat-transfer coefficients, lowered cost, longer lifetime, and scale resistance.

Evaporation phenomenon.—One of the critical limiting factors in any evaporation process is the resistance to mass transfer at the liquid-vapor interface. The nature of this phenomena is imperfectly understood. A knowledge of the water-vapor interface, the water structure at the interface, and a method to reduce the interface resistance would markedly increase the efficiency of distillation processes. Studies concerned with the structure of water and the properties of the liquid-vapor interface are to be expanded.

Materials.—Approximately 50 percent of the cost of desalinated water consists of the capital investment in the desalination plant. Large-scale desalting plants will require new approaches and imaginative ideas in order to make significant reductions in the costs and uses of materials of construction. Alternative materials of construction to the presently used ferrous materials will be investigated. The mechanism of attack of hot brines on concrete will be determined, and new concretes resistant to these brines will be investigated. The use of epoxy, PVC, and polyester fiberglass, ceramics, and other plastic materials for pipe, fittings, and pump components will be evaluated. The fundamentals of the adhesion of these materials to concrete will be probed.

Corrosion.—Salt water is one of the most hostile environments that materials of construction must withstand. A systematic study of corrosion phenomena to define how and why things corrode is in progress. The knowledge developed in this program is expected to lead to an understanding of the mechanisms of corrosion and to point a way to avoid it or to minimize it. The program can be accelerated and the information developed will be used to assist in the selection of materials for large-scale desalting plants.

Brine disposal-heat pollution.—Large-scale desalting plants will pose a potentially severe threat to the aquatic flora and fauna in the coastal area in the vicinity of such plants unless measures are taken to minimize the threat. Immediate programs will be initiated to determine the effect of heat pollution and brine disposal on aquatic environments, and how these effects possibly can be turned to advantage to improve the aquatic environment.

Increased emphasis will be placed on more economical methods for the recovery of potentially valuable byproducts, such as potassium, trace elements, fertilizer materials, etc.

Size of the program

The specific areas of research proposed above are related and interdependent. For example, in order to treat the problems of nucleation, growth, and transport in the freezing of saline water, we must understand better the generalities of transport processes, and the thermodynamic properties and detailed structures

of the substances involved. Similar examples could be offered for all other desalination systems. In each case, there are good clues to the fundamental questions, enough to make scientists and engineers believe that further study is warranted. As the program has increased in size and stature, increasing numbers of highly qualified and competent scientists and engineers are inspired by the opportunity the problem presents to devote their talents to the generation of the knowledge required to solve the problems of saline water conversion. By its very nature research requires freedom for the investigator to follow where his curiosity and interest lead, and confidence from the administrator, since some studies will pay off handsomely and others will yield less impressive results.

Currently proposals are being received in areas relevant to saline water conversion at a rate of approximately 600 per year. Thirty to forty percent of the proposals submitted suggest programs which are sufficiently meritorious to warrant support by OSW. The present funding of the research program allows for support of less than half of the meritorious proposals received. Indeed, as the program has become better known, it has attracted proposals from an increasing number of the Nation's foremost scientists and engineers, and it has been necessary to turn down an increasing proportion of proposals having high merit, in spite of the generally increasing level of support. The ultimate success and the extent to which desalination will become the method of choice for water supply in water-poor areas will depend in no small measure on our ability to attract and support the country's top talent in working on desalination problems. The proposed program for research will allow support for a greater fraction of those programs that can make significant contributions to the saline water conversion program.

The research program will insure the successful exploitation of the currently most developed technology and the vigorous and imaginative pursuit of other alternatives which may well prove to be superior in the long run. In conformity to the classifications of the Federal Council of Science and Technology, the program has been divided into the following four broad categories.

1. *Properties of water.*—The purpose of this effort is to obtain a comprehensive theoretical understanding of water and water systems to serve as a basis for separation and purification processes. The proposed program is required to achieve thorough knowledge of the thermodynamic properties of saline solutions that is essential to the understanding and evaluation of any desalination process. It is expected that these activities will soon eliminate the serious deficiencies of experimental data and understanding of the properties of multicomponent saline solutions, of ionic hydration and on the fine structure composition of pure water. A major improvement in the present status of theory concerning these phenomena and the liquid state itself will have been made.

2. *Separation processes.*—The investigations on separation and purification processes are designed to provide new information on thermodynamics, electrochemistry, phase and chemical equilibria and kinetics, and mass and energy transport in both physical and biological systems. This research is essential to further knowledge applicable to existing or potential saline water conversion processes, to evaluate ideas for new desalination techniques, and improve the technology and economics of known desalination methods. Analysis of present desalting technology and the anticipated technical advances indicate that no one desalination process will be adequate for all desalination requirements. In the next 5 years it is expected that the reverse osmosis process will move from the laboratory and pilot plant to the demonstration state. The energy requirement of present desalination processes is many times the theoretical minimum energy requirement. The research program is designed to drastically reduce the energy losses inherent in distillation, freezing, and other processes. Research under this category also includes general studies of ion exchange, effect of magnetic fields, fundamentals of freezing, polymer films, electrochemical separations, energy and material transfer, and many others.

3. *Interactions at boundaries of water systems.*—Inefficiencies in conversion processes are largely a result of events at surfaces or phase boundaries. The purpose of these studies is to understand and make use of physical and chemical processes on surfaces and at interfaces, and of colloid systems for separation and purification of water. Within the near future, boundary layer problems, cor-

rosion, mechanisms and rate of deposition of scale, and the interaction of materials with salt water systems will be far better understood, resulting in substantially lower capital investment for desalination plants of a given capacity.

Research projects in this category include studies on corrosion under various process conditions, with varying velocity, concentration, pH, oxygen content, heat flux, etc.; electrochemical corrosion mechanisms; corrosion prevention; corrosion of concrete; etc. These projects result in a very complete and comprehensive investigation of practically all phases of corrosion. Other current fundamental research investigations deal with ion transport across plant and microbial membranes, mass transfer in beds of particulate solids, effect of acoustical vibrations at interfaces, and others. It is hoped an accelerated and intensified effort on the development of improved materials (metals, alloys, concretes, polymeric materials), components of plants, etc., soon can be initiated.

4. *Properties of brackish waters, salts, brines, and byproducts.*—The objective of these studies is to obtain more economical separation processes by integrating saline water conversion with other endeavors such as mineral recovery, use of low-temperature energy, power generation, and combination with existing water systems. The particular problems associated with desalting brackish waters will receive detailed attention. Considerable emphasis will be devoted to brackish resources, minor constituents, biochemistry of, etc.

The minerals contained in saline waters are potentially available in unlimited supply. Multipurpose plants producing both power and potable water already have been designed. It is expected that the economic advantages of multipurpose plants, as well as mineral recovery, will soon be demonstrated. Currently under investigation are properties of sea water and its concentrates, nucleation of electrolytes, influence of vibrations on deposition of salts, minerals from sea water (e.g., potassium, magnesium, etc.), and the mechanism of calcium sulfate scale deposition. The proposed program will extend these studies and initiate a program directed to brackish water desalting.

Although the accomplishments of the research effort have been notable for such a short period, the present store of scientific information is not adequate to support all of the objectives of the desalination program. A sustained prodigious effort in fundamental research will be required before the solution of this most difficult problem can be attained.

STATEMENT OF EVERETT N. SIEDER, ACTING CHIEF, DISTILLATION DIVISION, OFFICE OF SALINE WATER ON THE PROPOSED DISTILLATION PROGRAM, FISCAL YEARS 1966-72

PROCESS DESCRIPTION AND PRESENT STATUS

Mr. Chairman and members of the committee, the Distillation Division is concerned with three general categories of distillation processes, namely:

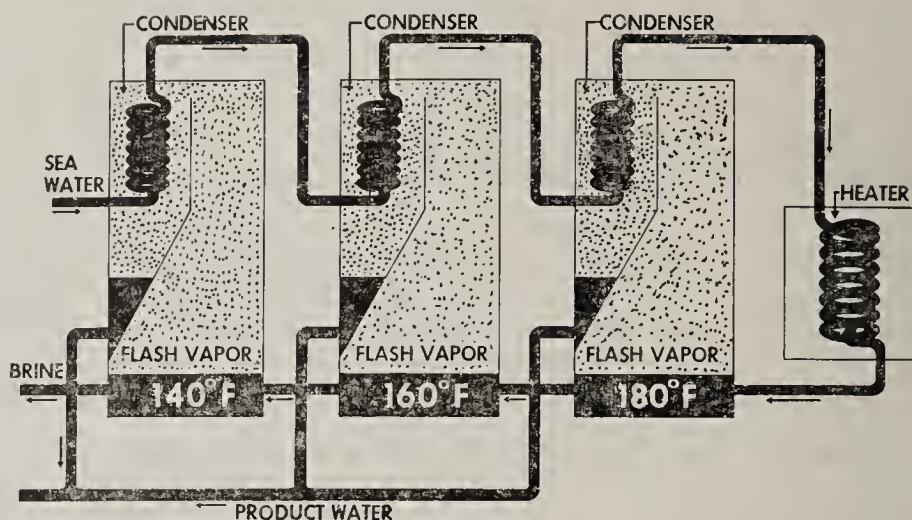
1. The multistage flash system as used in the San Diego demonstration plant now at Guantanamo;
2. The long tube vertical multiple effect system as exemplified by the Freeport demonstration plant; and
3. The vapor compression system now being demonstrated at the OSW plant at Roswell, N. Mex.

MSF

The multistage flash process, often called MSF, is so named because steam flashes from hot brine in a series of chambers or stages. The steam is condensed on cooling coils, associated with each flash chamber, to make fresh water. This process is further along at its development than the other two processes and is used in most production plants throughout the world.

The 1-million-gallons-per-day OSW plant in San Diego was the largest and most efficient of its kind when built. It eventually operated at 140 percent of design capacity. Technology developed in this plant has been incorporated in several recent production plants, one of which has a capacity of 1.7 million gallons per day.

FLASH DISTILLATION

*LTV*

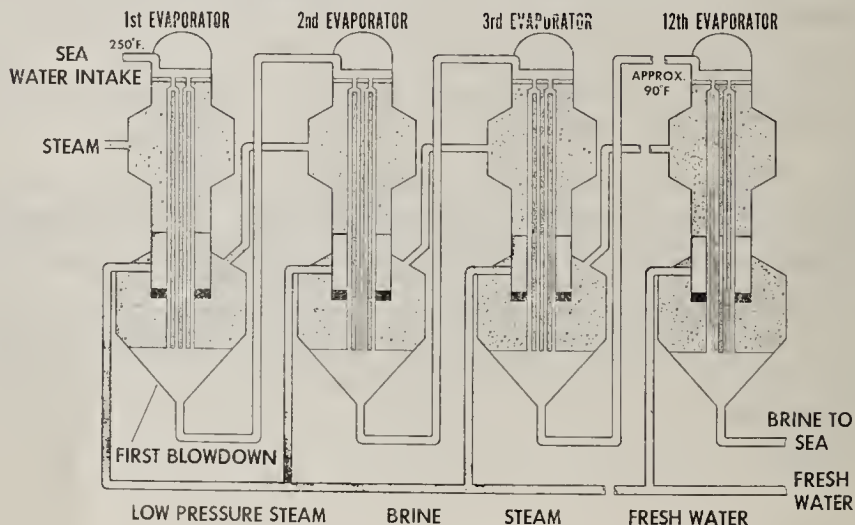
The long tube vertical (LTV) process has been used for years in various industrial evaporator systems, but until recently it has not been considered highly as a potential source of municipal and industrial water.

The 1-million-gallons-per-day OSW plant at Freeport, Tex., using this process, consists of 12 effects or individual evaporators, each comprising a bundle of long vertical tubes surrounded by a steam chest. Salt water is introduced in the top of the tubes and is partially vaporized as it flows downward on the inside of the tube walls. The steam so generated is used as a heating medium in each successive effect to cause further vaporization of the salt water feed; a high economy is thereby obtained as the heat of the initial steam is used over and over again. The steam, condensed in each effect, becomes the fresh water output from the plant. The Freeport plant, although getting off to a poor start, has for several years successfully made water at rated output and recently has demonstrated the possibility of producing water at 40 percent over capacity, if pumps were available to take it away. This process is now considered to be a close competitor of multistage flash.

LONG TUBE VERTICAL DISTILLATION PROCESS

DEPARTMENT OF THE INTERIOR

OFFICE OF SALINE WATER

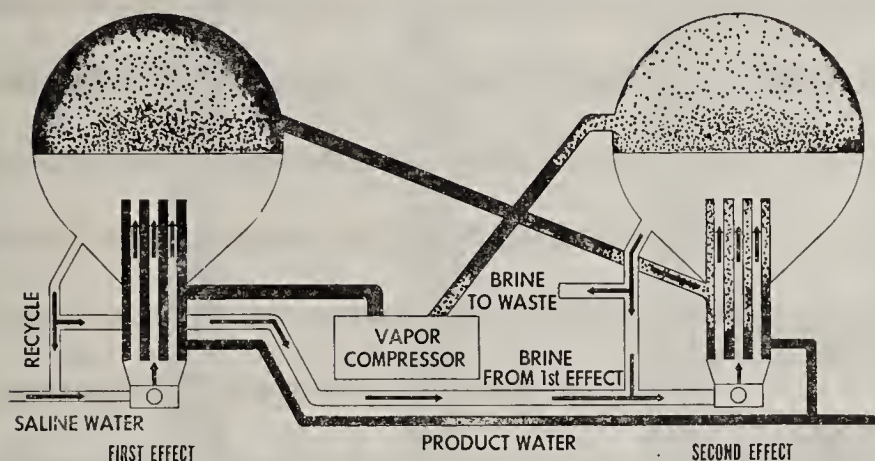


Vapor compression

The vapor compression process has been used commercially for over 25 years. Vapor-compression packaged desalting units were used by the Armed Forces in World War II. They are still being offered commercially for resort hotels in water-short areas and for shipboard use. The process to date has been characterized by high water cost and troublesome maintenance.

The vapor compression distillation process derives its name from the fact that the steam, produced by the initial evaporation of the brine feed, is pumped up to a higher pressure and consequent higher condensation temperature by a compressor where it is then utilized as the heat source for the initial evaporation. The steam, after condensation on the evaporator tubes, is pumped away as the fresh water product. The Roswell, N. Mex., 1 million gallons per day demonstration plant, which is of this type, met guarantees during the startup period, but has since been plagued with hydraulic and sealing difficulties. The process is unique in that energy is added by the compressor rather than as heat. It can operate with any conventional power source to drive the vapor compressor, e.g., electric motors, diesel engines, or gas turbines.

FORCED CIRCULATION VAPOR COMPRESSION DISTILLATION



The vapor-compression system is most promising where low-cost or off-peak electric power may be available and where cooling water and fuel are at a premium. This system is sometimes known as the heat pump process.

Point Loma replacement

The first and most important step, in our opinion, is to start construction of the advanced-technology San Diego replacement. The design, specifications, and bid package are complete and ready for release for bids. Schedules call for about 60 days for letting contracts and a year for construction. This plant will be of the multieffect, multistage system which incorporates such advanced features as:

- (1) High efficiency—twice the water output per pound of steam of any present-day plant.
- (2) Reduction in size of critical features, such as flash chambers, thus decreasing the overall cost of the plant.
- (3) The ability to operate at high temperatures and to utilize advances in scale reduction technology and byproduct processes.
- (4) More sophisticated instrumentation and automatic control systems.

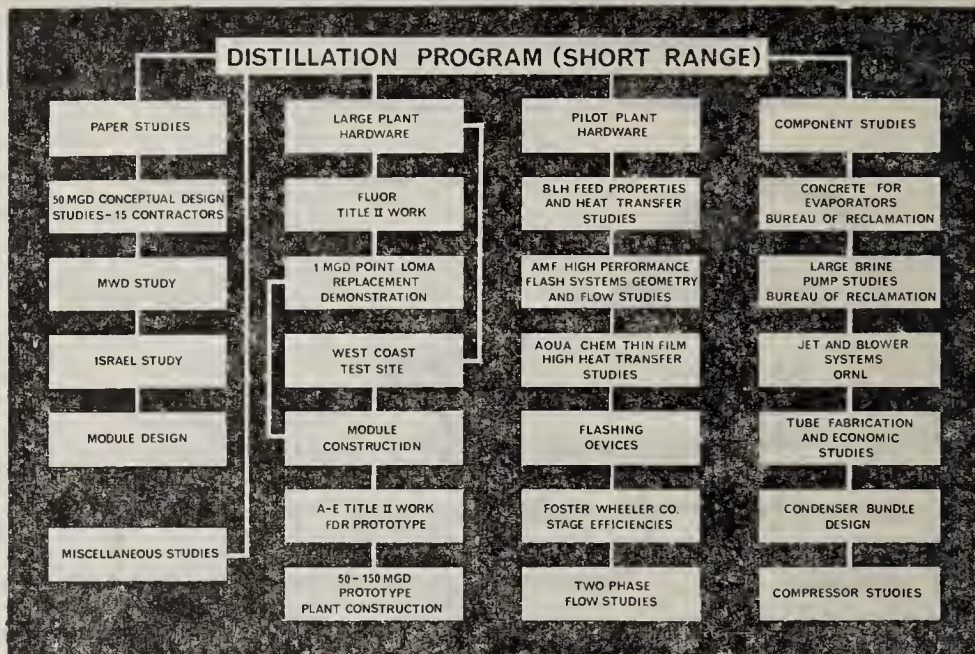
The construction and testing of this plant is necessary prior to design and construction of second generation flash plants.

Freeport

Plans for the Freeport plant call for installation of tubes of special configuration and design which should give higher heat transfer and much improved performance. As the cost of tubes in an evaporator may represent as much as 40 percent of its total cost, improvement in this area is important. Provision for special feedwater treatment methods are also planned for this plant to be in use within the next year. It is projected that the Freeport plant, when modified, will produce water at a cost 20 percent less than at present.

Roswell

The modifications planned for the Roswell plant will be directed first toward better scale control and correction of hydraulic deficiencies. Future plans call for major changes in compressor design or addition of entirely different compressor concepts which show promise in the pilot plant stage.



LARGE PLANT PROGRAM

Conceptual design studies

Conceptual design study contracts for a 50 million gallons per day plant have been issued to 15 contractors—architect-engineers, fabricators, and constructors. The purpose of these conceptual design studies is to have contractors present their ideas of processes and structural designs through the medium of a complete plant concept and supporting data. Such concepts must have received detailed study by them, and have been optimized by them, to indicate the lowest cost of water. The plant is to be designed on the basis of ground rules provided by the Office of Saline Water. These ground rules provide that the plant be capable of operating in conjunction with an electric generating plant, that it be suitable for a west coast site, and that it use technology based on known concepts, or data proven at the production or pilot plant level.

From these design studies, the Office of Saline Water will attempt to obtain the best composite or individual design concept for the development of a prototype plant. It is hoped the studies will lead to solutions of mechanical problems involved in large size desalting plants. The overall program will provide an economic evaluation of several known processes or combinations thereof. Although the ground rules provide that the evaporators be operable with dual-purpose plants, the information from the studies will be useful in future studies on single-purpose plants.

In addition to the 50 million gallons per day conceptual studies, the Office of Saline Water has contracted with the Oak Ridge National Laboratory for an advanced technology, 250 million gallons per day flash process conceptual design. This study is being made in much greater depth than the other studies and will consider features not yet reduced to practice nor necessarily proven in pilot plant studies. This evaporator system is to operate in a dual-purpose plant in conjunction with advanced reactor designs now under consideration by the Atomic Energy Commission for 1975 operation. Additional studies of this nature may be undertaken for the Office of Saline Water by Oak Ridge National Laboratory on other evaporative processes.

Supporting studies

Supporting studies have been initiated to develop the best components for critical areas in the plants of the future. These detailed investigations will be applicable to many or all of the distillation processes. Studies are being conducted by the Bureau of Reclamation at its Denver laboratories to generate technology necessary for the use of concrete for major components of large evaporator plants. Large test loops are being operated under conditions closely approximating those which will occur in the prototype plant. The Bureau of Reclamation is also assisting the Office of Saline Water in large pump studies.

Contracts have been let to certain pump suppliers for designs and specifications for large pumps needed for the prototype plant. Information on pumps of this size under the required operating environment has not been developed up to this time since the need has not existed.

Studies of other major components such as jets, blowers, compressors, tubes of special configuration, and tube bundles are being made by the Oak Ridge National Laboratory for the Office of Saline Water. The facilities of industry are also being used through contracts for the construction and operation of pilot plants based on the multieffect, multistage principle and studies of large-scale flash-chamber geometry. Studies are being undertaken on flashing devices which are the heart of any flash-distillation system.

The results of all of these studies should allow a decrease in margin of over-design without increasing the risk of performance failures in future plants.

Modular studies

The construction of modules and test sections of a new plant which represents a large scaleup factor from the present plant size is considered to be a necessary intermediate step. A module, as the term is used here, is a full size, or approximate full size, cross section of a large plant. It would consist of several full-size flashing stages with accompanying pumps, instruments, control and air-removal systems. In scaling-up from the largest plant of known performance, in the case of desalting from about 1.7 to 50 million gallons per day, there are many hydraulic and mechanical problems that must be solved before committing ourselves to the considerable expense of a full-scale plant. It is expected that through these modules we will be able to prove out concepts of hydraulic flow, heat transfer, and construction techniques before committing ourselves to the large plant, thus eliminating financial risks and possible delays in schedule.

Metropolitan water district

The Metropolitan Water District of Southern California, together with Interior and AEC, entered into a contract with the Bechtel Corp. for a detailed study to determine the engineering and economic feasibility of a combined nuclear-fired desalting and electric generating plant, producing water in the range of 50 to 150 million gallons per day with 200 to 750 megawatts of electric power.

The scope of work called for in the study is divided into three phases:

Phase 1 consists of a preliminary survey of possible sites on the southern California coast suitable for producing desalted water and with a means for introducing such water into MWD's distribution system. This phase will cover the economic feasibility of the several sites.

Phase 2 requires that a detailed investigation be made of such sites, selected under phase 1, which will include a determination of power-water production ratios, operating flexibility, and powerplant parameters based on the system requirements.

Phase 3 calls for a complete conceptual design of the optimum desalting and powerplant as determined from investigations of phase 2. This phase will provide detailed capital cost estimates, operating costs, and costs of water and

power. This phase of the report will make recommendations for use and distribution of the water and the sale of power, and will provide data for use in negotiating with the utilities.

Israel

Under an agreement with the State of Israel, the Department of the Interior, and the Atomic Energy Commission, a contract was let with Kaiser Engineers and the Catalytic Construction Co.

These two contractors, operating as a joint venture, will consider the feasibility of a dual-purpose water desalting and powerplant on the coast of Israel to provide 70 to 110 million gallons per day of desalted water together with 175 to 200 megawatts of electric power. In contrast to the MWD study, only one site will be considered.

The scope of work calls for a review and evaluation of reactors now commercially available and an investigation of more advanced reactors. The study also calls for the formulation of a development program to insure that there will be no unreasonable risk in meeting performance and that there will be no need for an unnecessary margin of overdesign required in the full-scale plant. The study will compare nuclear- and fossil-fuel costs and make recommendations as to the final fuel source.

The final report will provide detailed designs, capital costs, operating costs, and costs of water and power from the proposed plant.

Both the MWD and Israel studies should be completed by the end of the year. Both studies contemplate commercial operation of the plants by 1971-73.

PROPOSED MEMBRANE PROCESSES PROGRAM, FISCAL YEARS 1966-72 OF THE DEPARTMENT OF THE INTERIOR, OFFICE OF SALINE WATER

INTRODUCTION

With existing conversion technology, the most economical methods for converting the majority of inland brackish water supplies to potable water is via membrane processes.

A membrane may be defined as a physical barrier which allows the separation of salt from water by preferentially permitting the passage of salt while restricting the passage of water or which permits the passage of water while restricting the passage of salt. The energy or driving force for the separation may be a difference in concentration of the solutions separated by the membrane, an applied current, pressure, temperature, or a combination of these forces.

Membrane processes possess a number of attractive features which hold promise of significantly reducing the cost of converting brackish water and, with additional development, may find application for the conversion of sea water.

Among the attractive features of membrane processes is that no phase change is required to bring about the separation of salt and water. That is, water does not have to be converted to steam and then condensed back to the liquid state. Therefore, energy costs are held to an extremely low value. Also, since membrane processes operate at ambient temperatures, corrosion problems are minimal and less costly materials of construction may be used. Maintenance costs are also reduced.

The research and development activities in membrane systems, supported and encouraged by the Office of Saline Water have been extremely successful.

They have resulted in the electrodialysis process emerging as the most efficient and economical process for the conversion of brackish water in the range of 1,000 to 10,000 parts per million of dissolved salts, and they have resulted in the discovery of an entirely new membrane concept which holds promise for becoming an efficient and economical process for converting the whole range of saline waters from 1,000 parts per million up to, and including, sea water.

In addition, a number of new membrane processes are in the laboratory stage of development and show sufficient promise to justify additional bench-scale development work. They are the "transport depletion" process and the "electrogravitation transport depletion" process.

I would like to describe, briefly, each of the membrane processes to the committee—their advantages and limitations—and the approaches we propose to follow to realize the full potential of the membrane separation processes.

I. ELECTRODIALYSIS

The electrodialysis process differs from other conversion processes in that salt is removed from water rather than the water being separated from the salt.

When salts dissolve in water, they divide into equal numbers of positively charged particles called cations and negatively charged particles called anions. Electrodialysis may be defined as a process in which separation of these ions is accomplished by ion-selective membranes where the energy for separation is an applied electric current. The membranes used have a special property known as "ionic selectivity"; i.e., they can be made so as to allow the passage of either positively charged ions or negatively charged ions but not both. A simplified diagram of an electrodialysis stack is shown in figure 1. In the diagram (fig. 11), an electric field attracts anions to the right and the cations to the left. The "ion-selective" membranes allow ions to pass through in one direction only: permeable anion membranes (A) allow anions to pass through from left to right whereas permeable cation membranes (C) allow cations to pass through from left to right. Concentrated brine and fresh water are formed in alternate cells.

In the electrodialysis separation process, the quantity of electric current, the membrane area required and, therefore, the cost of the process depends on the amount of salt removed. Electrodialysis has an inherent economic advantage for desalting brackish water since the electrical energy requirement for separating salt from brackish water is much less than that which would be required to separate salt from sea water.

Electrodialysis became a practical reality with the development and introduction in 1948 of stable ion-selective membranes. Prior to that time, ion-selective membranes had low ionic selectivity, high electrical resistance and extremely short lifetime. After 1948, efficient membranes were able to be synthesized for the first time as a result of new developments in plastic technology.

Following the development of practical ion-selective membranes, commercial development of the electrodialysis system came about rapidly and the first production installation went on stream in mid-1954. At the present time, there are over 100 electrodialysis plants in operation throughout the world.

The largest plant currently in operation is the installation in the city of Buckeye, Ariz., which has a design capacity of 650,000 gallons per day.

The economic potential of electrodialysis for desalting brackish water resulted in its selection in 1959 as the process to be demonstrated in the first brackish water demonstration plant. This 250,000-gallon-per-day plant, built at Webster, S. Dak., by the Austin Co. using the Asahi Chemical Industry Co., Ltd., stack design, became operational in the fall of 1961. Since that time, the plant has continuously supplied water to the city of Webster. The plant has generated much useful information, particularly with respect to the economics of the system and the operational problems that can arise during long-term usage of electrodialysis equipment.

A. Electrodialysis limitations: Potential areas of improvement

While today there is relatively widespread application of the electrodialysis process, not all brackish waters can be converted economically.

Significant gains in economy by making improvements in the technology of the process are possible. Potential areas of improvement include development of more efficient membranes and also improved hydraulic system.

To understand where these improvements can be made, it becomes necessary to describe the basic mechanism of ion transport through ion-selective membranes.

When immersed in an aqueous solution, the structure of an ion-selective membrane can be considered to consist of a solid phase and a liquid phase. The solid phase or body of the membrane is an insoluble polymerized hydrocarbon matrix to which are attached fixed ionic charges. These fixed charges are positive for anion selective membranes and negative for cation selective membranes. The membranes are porous and within the pores, or liquid phase, are an equal number of mobile ions of opposite charge.

As an example, a cation membrane of the sulfonated polystyrene type immersed in a solution of sodium chloride is shown in figure 12. Within the body of the membrane, sulfonic acid groups are chemically bound to the insoluble polystyrene network. In aqueous solution, the sulfonic acid group dissociates to form negatively charged fixed ions. At equilibrium, due to the requirement for electroneutrality, there is an equivalent number of mobile positively charged ions or sodium cations within the membrane. These sodium cations occur within the pores or liquid phase of the membrane and are capable of migration.

If a DC potential is applied to the system, both the mobile sodium and mobile chloride ions will take part in the transport of electricity through the bulk solution. In the cation membrane, however, it is found that almost all current is carried by the sodium ions. The electrostatic repelling forces between the fixed negatively charged sulfonate ions prevent the chloride ions from entering and migrating through the membrane phase. In a similar manner, fixed positive ions in an anion selective membrane prevent sodium ions from entering into the anion selective membrane. This "ion exclusion effect" is largely responsible for the ion selective action of these type membranes. This description of ion transport, as given above, is based on an idealized system. In actual operation, electrodialysis is more complex since a number of transport processes occur simultaneously. The major transport processes which occur in ion-selective membranes are shown in figure 13.

Counterion¹ transport constitutes the major electrical ion movement in the process. Co-ion transport which also occurs is undesirable and should be made as small as possible; this is dependent upon the selectivity of the membrane and upon the concentration gradient across the membrane. Water transfer, resulting from ion transport, will occur. This can be in the form of water of hydration of the mobile ions, such as sodium, and as water carried along with the ions and not tightly bound.

In practical electrodialysis, the total water transfer caused by electrical current is generally referred to as electro-osmosis. Osmotic water transfer also occurs and takes place in the same direction as the salt transfer. Osmosis and electro-osmosis are undesirable effects which tend to limit the usefulness of electrodialysis as a method of concentrating electrolytic solutions. Finally, diffusion of electrolyte can occur from the concentrating stream to the diluting stream due to the concentration gradient.

In summary, the efficiency of the electrodialysis process can be considerably reduced by the counter effects of electro-osmosis and osmosis, diffusion and co-ion transport. These unwanted transport processes can be minimized by the use of membranes with high ion-selectivity, that is, negligible permeability toward ions of the same charge as the fixed ions of the membrane by controlling the pore size, and by controlling the distribution of fixed charges within the membrane matrix.

While relatively efficient ion-selective membranes have been developed and are currently in use, there is still need for further improvement to more closely approach the properties of an ideal membrane; in fact, choice of membrane types for any application is likely to be a matter of compromise.

We propose to initiate a membrane investigation and development program to further improve membrane properties. We believe improved efficiencies may be achieved by developing membranes of low resistance, higher charge density, optimum pore size, and minimum thickness. Minimum thickness is desirable from the standpoint of both associated reductions in the cost of membrane surface and an improvement in electrical conductance.

Further cost reductions in the electrodialysis process can be achieved by minimizing the effects of polarization. Polarization or film depletion is a major limiting factor which has kept the cost of water production by electrodialysis high. If it were not for this limitation, plants could be designed to operate at an economic optimum current density in lieu of the lower current density that we are now forced to use.

The phenomena of polarization arises from the concentration gradients which occur at the membrane interfaces. At, or near, the interface of a membrane, the solution will tend to become depleted of ions. If the current density is not too high, the depletion will be largely balanced by diffusion of ions from the bulk solution to the membrane interface. There is, however, a critical current density at which diffusion will be incapable of furnishing electrolyte to the membrane interface. With a further increase of current density, the voltage rises sharply and all the current above the critical value is carried by hydrogen or hydroxyl ions which result from the disassociation of water. This phenomenon is called film depletion or polarization. Polarization causes pH disturbances at the interface, loss of current efficiency and high electrical resistance. If pH sensitive substances are present in the solution, they may be precipitated causing damage or plugging of the membranes.

¹ All ions in a ion-selective membrane having a charge opposite from the fixed ions; i.e., in the example given previously, sodium cations within the cation selective membrane.

We propose to initiate a program with the objective of minimizing polarization effects. As part of this program, improvements in the hydrodynamics of the system will be investigated. Polarization can be minimized by inducing turbulence, and by insuring that local stagnant flow areas are eliminated. This will require improvements in membrane separator designs and the development of methods to induce turbulence in the solution adjacent to the membrane.

We also propose to investigate the use of electrical and thermal methods to counter the effects of polarization. Electrical field disturbances or "pulses," created by reversing the polarity of the electrodes, can be used to momentarily disrupt the steady state concentration gradients that occur at the membrane solution interface. This method has been tested at the Webster, S. Dak. electro-dialysis plant with promising results. Additional work is required to perfect the techniques and to obtain data over a wide range of operating conditions.

It is known that there is a reduction in solution resistance and, therefore, an increase in the maximum allowable limiting current density as the temperature of the feed water to be demineralized is increased. We propose to investigate the effects of temperature on waters of varying composition in order to determine if preheating the feed water will open another avenue for reducing the cost of converting brackish water by the electro-dialysis process.

B. Cost factors in electro-dialysis

The cost of converting water by electro-dialysis will vary widely due to the strong dependence of the electro-dialysis process on the total salinity, chemical composition and temperature of the water. A recent study was made for the Office of Saline Water to determine the present-day cost of electro-dialysis conversion for specific base case waters using uniform design and economic criteria. In the study, costs were determined for plants with capacities of 250,000 g.p.d. to 10 m.g.d. The extent of potential cost reductions by lowering of membrane costs and assuming operation at the economic optimum current density was also determined.

The estimated present day cost of converting brackish water at Buckeye, Ariz. and at Webster, S. Dak. is shown in figure 4. These curves are significant because they also show the strong influence of chemical composition of cost. Though the water at Webster has a lower salinity than that at Buckeye, the cost of converting Webster water is about 50-80 percent higher due to the high calcium content and lower temperature of the Webster water.

The effect of low cost membranes and operation at optimum current density is shown in figure 5. While these curves are based on a 1 m.g.d. plant at Webster, they would be representative of costs experienced in other plants.

For a 1 m.g.d. plant operating at the present-day limiting current density, with a membrane price of \$1.88 per square foot and a service life of 3 years, the cost of water is estimated to be 73 cents per 1,000 gallons. If a membrane cost of 50 cents per square foot and a service life of 7 years is assumed, the cost decreases to 52 cents per 1,000 gallons. If the current density is raised to the economic optimum level, there is a further reduction to 42 cents per 1,000 gallons.

Overall, a reduction in cost of between 40 and 50 percent may be anticipated if we develop means to allow operation of the electro-dialysis process at an economic optimum current density and if we develop low cost membranes.

C. Outlook for future advances in electro-dialysis conversion technology

With the current state of technology, the economics of the electro-dialysis conversion limit its application to waters containing less than 4,000 parts per million of dissolved salts. We believe that new knowledge and improvements in technology resulting from an intensive research and development program in electro-dialysis will allow us to extend the useful range of electro-dialysis to waters of considerably higher salt concentration. In areas where very cheap energy is available, using membranes of high conductivity, high ion-selectivity, low permeability to water, and good mechanical strength and with the development of more sophisticated cell designs than those presently in use, it may be possible to extend the application of electro-dialysis conversion techniques to include economically competitive sea water demineralization.

II. TRANSPORT DEPLETION

The "transport depletion" process is a variant of the electro-dialysis process and involves the substitution of a nonselective membrane permeable to both cations and anions in place of one of the more expensive ion-selective membranes. The transport depletion cell consists of compartments formed by the alternate

arrangement of ion-selective membranes and neutral nonselective membranes. One of the promising features of such a system is the possibility of materially reducing the cost of membranes.

The mechanism of "transport depletion" is very similar to that of electrodialysis. When a voltage is applied across a transport depletion cell, cations (Na^+) move toward the cathode and anions (Cl^-) move toward the anode as they do in electrodialysis. Because of the difference in velocity of the ions in solution and in the membrane, the cations move through the cation permeable membranes faster than they can be supplied to the membrane-solution interface by diffusion. The cations then emerge from the opposite side of the membrane faster than they can diffuse into the solution. After a short time, a concentration gradient across the membrane is established—resulting in the formation of compartments in the cell which are alternately enriched and depleted of salt. The nonselective membrane in the system serves to retard the diffusion of ions from the concentrated cells back into the depleted cells.

The transport depletion process has been demonstrated on a laboratory scale and, as mentioned earlier, there were implications that membrane costs could be reduced, high current densities could be used and polarization and membrane fouling problems could be minimized.

We envision the following exploratory program to assess the economic potential of the transport depletion process:

- (1) Selection and characterization of membranes to determine optimum properties required.
- (2) Characterization of the membranes by dynamic methods to investigate polarization effects, efficiency, current consumption and limits of separation efficiency.
- (3) Evaluation of the data obtained to determine the economic potential of the process and identification of those areas requiring additional development effort.

III. ELECTROGRAVITATIONAL DEPLETION PROCESS

The "electrogravitational depletion process" is also a variant of the electrodialysis process and involves the use of a series of membranes each of which possesses the same charge, either positive or negative, in contrast to the electrodialysis process which uses a series of alternating positively and negatively charged membranes.

In its simplest form, the EDP system consists of a rectangular container in which are hung sheets of an ion-selective membrane, and a means for applying a direct current in series through the liquid and the membrane sheets. The process is illustrated in figure 6. Because of the ion-selective properties of the membranes, the passage of current results in the demineralization of a thin layer of solution adjacent to one side of the membrane. Simultaneously, a concentrated layer of solution is formed adjacent to the other side of the membranes. Since the depleted layer has a higher resistance to the passage of current than the rest of the solution, there is an increase in temperature of the depleted layer. The combined effect of demineralization and electrical heating on solution density establishes a convective flow, in which the demineralized layer rises and the concentrated layer sinks along the membrane surfaces on which they form. The effect is to convert a homogeneous solution into one in which a large difference in concentration exists between the top and bottom. Raw saline water is introduced at the bottom of the unit and desalted product water overflows above the membranes.

The EDP process has already been demonstrated on a laboratory scale and it has been shown that solutions of sodium chloride can be demineralized. However, additional studies are necessary to determine the ultimate economic potential of the process.

We envision an exploratory program to investigate the following system variables:

- (1) Cell configuration—so that the number, spacing and height of the membranes can be varied.
- (2) Membrane selection—membranes to be characterized in terms of porosity, water transfer and permselectivity to determine optimum properties required.
- (3) Current density—to be investigated with respect to polarization effects, efficiency, current consumption per unit of product.

(4) Hydrodynamic flow—to be varied in order to determine the optimum feed-to-product ratio.

(5) Feed water salinity—to be varied to determine the upper limits of separation efficiency with waters up to sea water concentration.

The data obtained in the experimental program will be analyzed to determine the economic potential of the process and will also be used to identify those areas where additional research and development may be necessary to realize the optimum efficiency of the system.

A chronological schedule for the proposed electro dialysis development program is shown in table 1.

TABLE I ELECTRODIALYSIS DEVELOPMENT PROGRAM SCHEDULE

	1967	1968	1969	1970	1971	1972
Pilot Plants						
Initial Low Salinity, High Hardness Water, Pilot Plant: 25-50,000 gpd	Construct	Test				
Improved Low Salinity, High Hardness Water, Pilot Plant: 25-50,000 gpd	Construct	Test				
Initial High Salinity, Low Hardness Water, Pilot Plant: 25-50,000 gpd	Construct	Test				
Improved High Salinity, Low Hardness Water Pilot Plant: 25-50,000 gpd		Construct	Test		Sea water test	
Initial High Salinity; High Hardness Water Pilot Plant: 25-50,000 gpd		Construct	Test			
Improved High Salinity; High Hardness Water Pilot Plant: 25-50,000 gpd			Construct	Test		Sea Water Test
Test Bed Plants						
Test Bed Plant: Low Salinity, High Hardness Water 250-500,000 gpd			Design & Construct	Operation		
Test Bed Plant: High Salinity, Low Hardness Water; 250-500,000 gpd			Design & Construct	Operation		
Test Bed Plant: High Salinity, High Hardness Water; 250-500,000 gpd				Design & Construct	Operation	
Membrane Development						
Feedwater Pretreatment Studies; Application to Polluted Waters and Acid Mine Waters						

IV. REVERSE OSMOSIS

During the 1950's, the Office of Saline Water supported pioneering research at the University of Florida where it was demonstrated, for the first time, that it is possible to effectively desalt sea water by reverse osmosis. This research, and that subsequently conducted at the University of California in Los Angeles, led to a quickening of research and development activity over the last 3 years which has brought this new process into national prominence as a most promising method of desalination.

The principles of the process and the origin of the term "reverse osmosis" are illustrated in figure 7. If a saline solution is separated from pure water by a semipermeable membrane (one which permits the passage of water but prevents the passage of salt), pure water will flow spontaneously into the saline solution with the necessary driving force being provided by the difference in salt concentration between the two solutions. This flow will continue until an equilibrium is established. That is, until the hydrostatic pressure of the salt solution is just sufficient to prevent the further flow of pure water into the saline water chamber. The movement of pure water into the saline water is called osmosis, and the pressure at which the flow of pure water ceases is known as the equilibrium osmotic pressure of the saline solution.

The normal process of osmosis can be reversed if sufficient pressure is applied to the saline solution to overcome the osmotic pressure. Application of a pressure in excess of the osmotic pressure will cause pure water to flow out of the saline solution in a direction opposite to the osmotic flow, hence, the term "reverse osmosis." The driving potential in this reverse case is pressure while in normal osmosis, the driving potential is the difference in salt concentrations between the two solutions.

This principle can be readily translated into a conversion process assuming that appropriate membranes are available. The essential features of a reverse osmosis desalination system are illustrated in figure 8. Feed water is pumped to a pressure in excess of its osmotic pressure and passed through a separation unit which contains semipermeable membranes. A portion of the water permeates the membranes and is collected as desalinated water at atmospheric pressure on the other side of the membrane. The concentrated brine, still at essentially its entering pressure, is passed through a recovery turbine to conserve its contained energy, and discarded.

Research on the reverse osmosis principle was encouraged initially, and continued to be encouraged, by the promise this process holds for outstanding economy in the conversion of saline waters. Advantages include the following:

- (1) Low energy requirements. No phase change is involved which inherently makes for a lower thermodynamic energy requirement and tends to simplify the operations. This is in contrast to the distillation, freezing, and hydrate processes where phase changes are necessary.
- (2) Simplicity of the system with respect to equipment.
- (3) The only energy input is electrical energy.
- (4) Normal temperature operation resulting in mineral corrosion and scaling problems.
- (5) General applicability to both sea and brackish waters.

A. Membrane limitations: Potential areas of improvement

From the beginning, it was evident that successful and economic application of the reverse osmosis process depended on a satisfactory membrane. A reverse osmosis membrane, in addition to having adequate life and reasonable cost, must possess the following properties: (1) Be selective enough to permit the passage of water from the saline to the fresh side with low enough salt content to be potable, and (2) be porous enough to pass this water at a high rate under reasonable overpressures. No membranes of this nature existed when the process was first proposed.

In 1953, with the encouragement and financial support of the Office of Saline Water, the initial research program to find a semipermeable membrane for strong electrolytes was undertaken at the University of Florida by Dr. C. E. Reid. The work resulted in the discovery of the salt rejection properties of cellulose acetate and the demonstration that the purification of sea water by this method is technically feasible. However, that work was limited to commercially available films with extremely low water transmission ratio and it was clear that additional membrane development was required.

Following the work by Reid at the University of Florida, the Office of Saline Water supported research efforts which attempted to analyze the mechanism of membrane functions with the ultimate objective of obtaining a membrane with the high water transmission rates that would be required for a practical reverse osmosis process. Other investigators outside of the Office of Saline Water program also continued to explore the membrane problem. Among these was Dr. S. Loeb of the University of California who, in 1960, developed a technique for the fabrication of cellulose acetate membranes which converted sea water to fresh water at suitable flux rates. Using Mg (ClO₄)₂ to modify the cellulose acetate membrane, Loeb obtained transmission rates of 5 to 11 gallons per square foot of membrane surface per day. These rates exceeded the flux rates obtained at Florida by 50 to 100 fold. On a laboratory scale of production, membranes are routinely fabricated which permit product water flows of 5 to 10 gallons per day per square foot with salt rejections of 95 to 99 percent, and even higher flows for treatment of brackish water where a lesser degree of salt removal is required to produce potable water.

Currently, it is estimated that about two-thirds of the cost of water produced by reverse osmosis represents the cost of membranes and their replacement. Accordingly, we propose to increase our emphasis on membrane research and development.

Membrane replacement costs can be reduced sharply by: (1) Increasing the potable water flux through the membrane, (2) reducing the unit cost of the membrane, and (3) increasing membrane life.

With respect to item (3), membrane life, the deterioration of cellulose acetate membranes with time had been viewed as a serious limitation of their ultimate usefulness; but recent work has shown that the lifetime behavior can be markedly improved through hydrogen-ion concentration adjustment of the feed water. Figure 9 shows the results of some lifetime experiments performed at the General Atomic Division of General Dynamics Corp. under an Office of Saline Water con-

tract. Here, the salt permeation constant, a measure of the rate at which salt leaks through the membrane, is shown as a function of time in test. The two experiments in which hydrogen-ion concentration adjustment is being used are still in progress, and measurable membrane deterioration has yet to be observed.

The membrane material being produced at the present time gives salt rejections per pass of 96 to 99 percent when operating in the 1,000 to 1,500-pounds-per-square-inch range. Thus, with sea water feed, potable water (500 parts per million) will not be produced in one pass except under optimum conditions. This too, had been considered to be a serious limitation of the ultimate usefulness of the process. However, workers at the Aerojet-General Corp. supported with funds provided by the Office of Saline Water showed that the salt rejection of cellulose acetate membranes could be maintained at a sufficiently high level to accomplish the conversion of sea water to potable water in a single pass. This was accomplished by the addition of small amounts of polyvinyl methyl ether to the feed water. A better solution would be the development of a higher rejection membrane through membrane research or improved membrane manufacturing techniques. In our proposed program, we will increase efforts directed toward: (1) improvement of cellulose acetate membranes; (2) alternative membranes which combine suitable permeation properties with greater durability; and (3) problems of membrane production on a commercial scale.

B. System design and development

During the past 3 years, the Office of Saline Water has accelerated its development effort on the reverse osmosis process. Progress made during that time has convinced us that the decision to emphasize reverse osmosis is a prudent one and that the process can be reduced to large-scale practice during the next few years if a vigorous development program is implemented. Parametric studies and conceptual design studies invariably show reverse osmosis plants to have much lower energy requirements than the typical energy requirements of distillation plants. For example, the best evaporative conversion plants in operation consume approximately 30 times the minimum theoretical energy required for the separation of salt from water, whereas the reverse osmosis process consumes approximately 7 to 9 times the theoretical energy.

This low-energy requirement was shown to exist on qualitative grounds before any of the current work on reverse osmosis was initiated. It is the low-energy requirement that is probably the most attractive feature of the process.

Work now in progress and which we propose to accelerate is aimed to a considerable extent at determining and minimizing capital costs.

At the present time, the Office of Saline Water has two promising design concepts under investigation—the approach taken at Aerojet-General Corp. which is based on a plate-and-frame concept as shown in figure 9a and the approach taken at General Atomic Division of General Dynamics Corp. which is based on a spiral modular concept as shown in figure 10.

The most advanced of the two designs on the basis of reduction to practice, is the plate-and-frame concept. A 1,000-gallons-per-day module has been tested on both brackish and sea water with extremely encouraging results. The spiral modular concept has been successfully tested on brackish water and work is currently in progress to adapt the design for sea water application.

C. Cost factors in reverse osmosis systems

The reverse osmosis process is still in an embryonic stage of development. There are no pilot or demonstration plants in existence capable of producing definitive cost data. However, in the course of the research program, continuous economic analysis has been necessary to evaluate equipment designs, materials, and membrane improvements particularly as those variables affect the cost of future plants. Based on that experience, estimates have been made which show that the cost of converting sea water by reverse osmosis should be less than \$1 per 1,000 gallons and for brackish water less than 50 cents per 1,000 gallons.

Some of the factors affecting the cost and the improvements already achieved are more indicative of economic progress in reverse osmosis than generalized dollars and cents estimates. The key to the economics of reverse osmosis is the membrane. The life, durability, and cost of fabrication are the important factors. A few years ago the price of a cellulose acetate membrane was estimated at about \$3 per square foot. The question also was raised as to the feasibility of performing economically, in quantity production, the series of steps involved in membrane fabrication. During the past 2 years, it has been shown that membrane fabrications lends itself readily to mechanization and that production of the membrane on a continuous basis is entirely feasible. It has been noted also that the cost of the raw materials in a square foot of cellulose acetate membrane

is only a few cents. These experiences lead us to believe that a cost of 25 cents to 50 cents per square foot of membrane is a realistic goal and attainable with present technology. The problem of building machines for membrane production appears to be one of engineering design and testing, not one of innovation.

The life of service period of a membrane is naturally important in determining the cost of the process. In the beginning there was some question about the validity of the predicted 6 months service life. However, actual operating experience on the 1,000 gallons per day test module fully supports this estimate of service life and tests now in progress indicate that membrane lifetime may be lengthened considerably by adjustment of the hydrogen-ion concentration of the feed water.

Higher flux rates would normally be expected to reduce costs and some further improvements are expected in this area. However, the chief economic improvement is not to be expected in higher flux rates alone since fluxes are already comparatively high and a point will be reached where other factors began to offset the effects of increased fluxes.

The first conceptual design studies made for large-scale reverse osmosis plants, showed that the membrane-containing structures accounted for over half of the total equipment costs in those plants. Since that time, design effort has centered on the development of membrane modules which may be installed inside sections of standard size carbon steel pipe. The modular approach reduces the cost of the pressure vessels to the cost of the pipe and suitable fittings, and makes the contribution of this component less than 25 percent of the total equipment cost.

V. PROGRAM OUTLINE

In order to realize the full potential offered by the reverse osmosis concept, the Office of Saline Water proposed the following engineering and development program:

A. Membrane development

Investigations seeking improvement in the properties of cellulose acetate membranes and the search for alternative membranes with properties superior to cellulose acetate will be accelerated.

B. Module design and module construction techniques

The membrane module is the key component of a reverse osmosis plant. Its properties largely determine operating parameters, and its costs are the greatest source of uncertainty in present cost projections. For this reason, a major program on module development and the development of techniques for manufacturing membrane modules is suggested.

C. Design and construction of two 50,000-gallon-per-day prototype pilot plant modules

Each of these modules will embody different design features and will serve primarily to test the feasibility of the design and the manufacturing techniques used in fabricating the modules. The design of these plants will be such that they can be used for both brackish and sea water applications.

D. Design and construction of two 250,000-gallons-per-day test-bed plants

These two plants will be specifically designed for operation on brackish water. The operation of the pilot plants, and experimentation with them, would be directed toward the investigation of the validity of the criteria used in designing them and to provide definitive data for engineering design of larger plants.

E. Engineering design of a 1-million-gallons-per-day experimental brackish water test-bed module

At this point in the development program, the design showing the best operating performance through the 50,000- and 250,000-gallon-per-day test States will be selected for further development.

F. Construction of the 1-million-gallons-per-day experimental brackish water test-bed module

G. Operation of the 1-million-gallons-per-day experimental brackish water test-bed module

It is expected that during operation, critical areas for plant improvements and cost reductions will become apparent. It is too early to predict just what these areas will be, but an allowance for further development work is included in the suggested program in order to immediately exploit those findings which may lead to significant cost reductions.

H. Sea water program

Concurrent with the development effort on the brackish water applications of reverse osmosis, design and test effort to develop an optimum system design for sea water application of reverse osmosis will also be conducted.

I. Selection of design criteria for sea water plant

The 50,000- and 250,000-gallons-per-day prototype modules used to obtain test data for the design of the brackish water test-bed plant will be modified and adapted for sea water operation. The data obtained from operation of those prototype modules plus the operating experience gained from the 1-million-gallons-per-day test-bed brackish water plant will be used to develop the design for a 1-million-gallons-per-day sea water test-bed plant.

J. Study of feed water composition variables on membranes and plant performance

The chemical composition of sea water throughout the world is relatively constant. Except in the vicinity of harbors and river outlets where organic pollution may be encountered, we do not foresee major problems arising which would lead to the need for expensive preconditioning of feed water. Brackish water, however, presents us with a number of potential problems. The composition of brackish water varies widely among different sources and is even known to vary in different wells in the same aquifer. In brackish water, one may encounter heavy metals at a much higher concentration than in sea water, suspended matter such as colloidal clay, organic matter, sulfur, and other materials which may adversely affect reverse osmosis membranes. We propose to determine the effect of those contaminants on membrane performance and to develop means for their control in order to insure optimum membrane performance.

A chronological schedule for the proposed reverse osmosis development program is shown in table 2. It calls for startup of a 1-million-gallons-per-day brackish

TABLE II REVERSE OSMOSIS DEVELOPMENT PROGRAM SCHEDULE

	1966	1967	1968	Fiscal Year 1969	1970	1971	1972	1973
Initial 250,000 gpd Brackish Water Test Bed Plant								
50,000 gpd Pilot Unit	Construct	Test						
250,000 gpd Test Bed Plant (Brackish)	Design & Construct		Operation					
Improved 250,000 gpd Brackish Water Test Bed Plant								
50,000 gpd Pilot Plant		Construct		Test				
250,000 gpd Test Bed Plant			Design & Construct		Operation			
1,000,000 gpd Brackish Water Test Bed Plant						Design & Construct		
Sea Water Test Bed Plant								
50,000 gpd pilot plant modified and adapted to sea water			Design & Construct		Test			
250,000 Test Bed Plant for sea water					Design & Construct		Operation	
1,000,000 gpd Test Bed Sea Water Plant							Design	
Studies in Membrane Development and Manufacturing Techniques								
Includes operation of small test units to determine life, durability, and effects of water quality								
Studies of Feedwater Preconditioning Treatment								

water test-bed plant in 1972. We believe that goal is attainable if funds are made available for the program.

VI. BRACKISH WATER TEST FACILITY

The proposed membrane program deals primarily with engineering development and much of the program involves construction, testing, and operation of bench-scale equipment, pilot plant modules, and complete experimental test-bed plants.

The membrane processes hold most promise for initial application to the conversion of low and moderately saline waters. For this reason, the first goal in

the membrane program will be the development of the most efficient and economical process for the conversion of inland brackish water supplies.

To attain that goal, it will be necessary to test proposed processes and system designs and to obtain operating and economic data for each of the advanced design concepts selected for intensive development. Since processes and designs will be competing with each other, it will be necessary that the test modules and the processes embodied in them be operated under standard conditions.

To insure that standard conditions are provided, we are requesting funds for the establishment of an inland brackish water test site to provide adequate facilities for the simultaneous operation of between 6 and 12 pilot and test-bed plants. The daily feed water requirements for those plants will vary between 50,000 and 2,000,000 gallons per day and facilities will need to be provided to handle the disposal of up to 1 million gallons per day of brine.

FIGURE 1

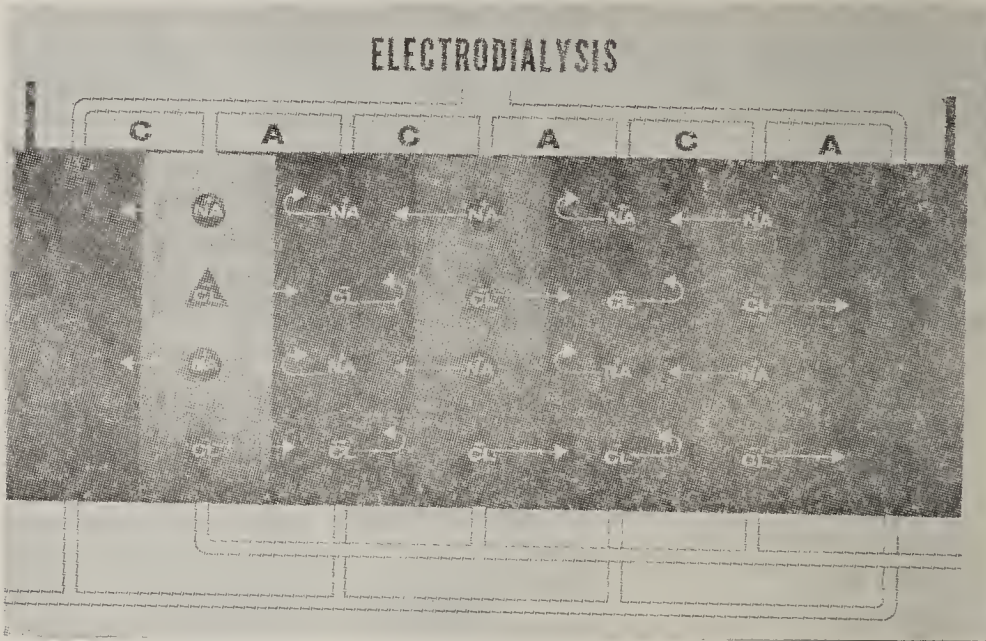


FIGURE 2

ELECTRODIALYSIS CELL

SINGLE CELL SURROUNDED BY SODIUM CHLORIDE (NaCl) SOLUTION
SALT REMOVED FROM THE CENTER

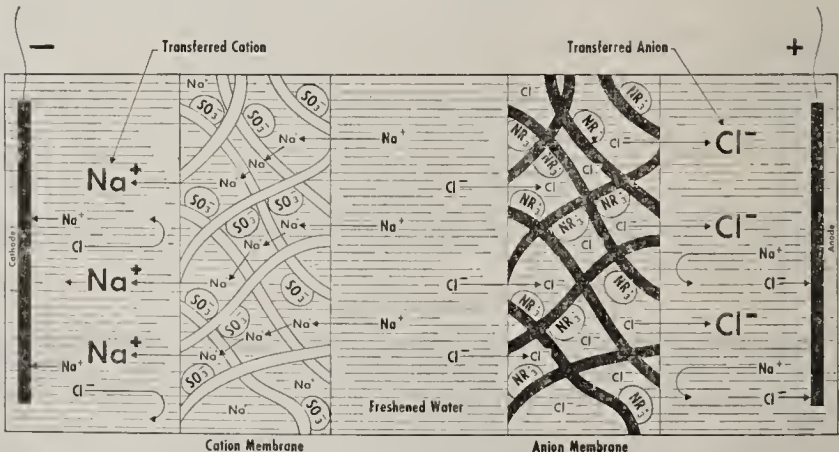


FIGURE 3
TRANSPORT MECHANISMS
IN ELECTRODIALYSIS

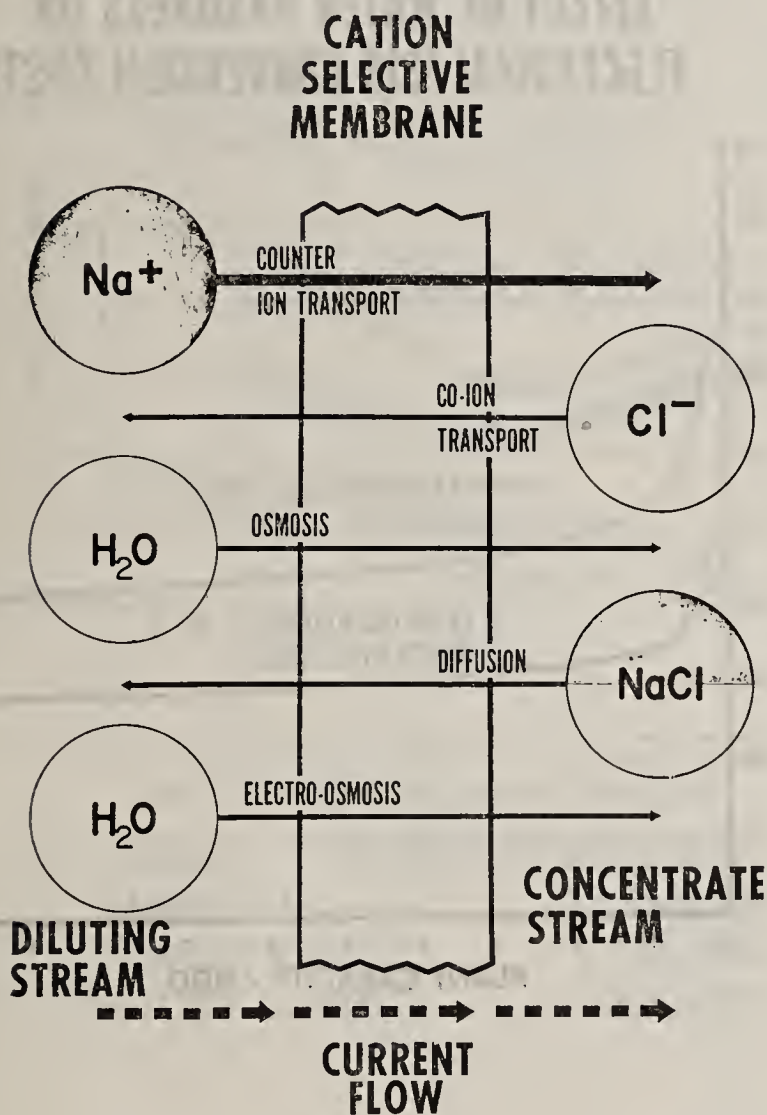


FIGURE 4

EFFECT OF WATER HARDNESS ON
ELECTRODIALYSIS CONVERSION COSTS

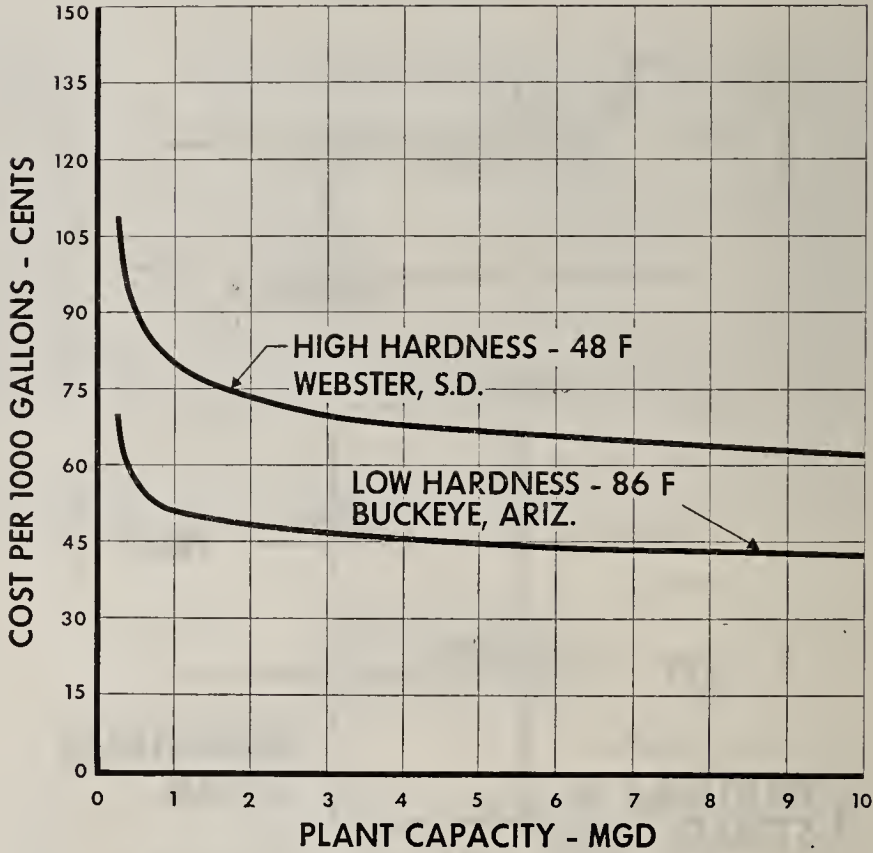
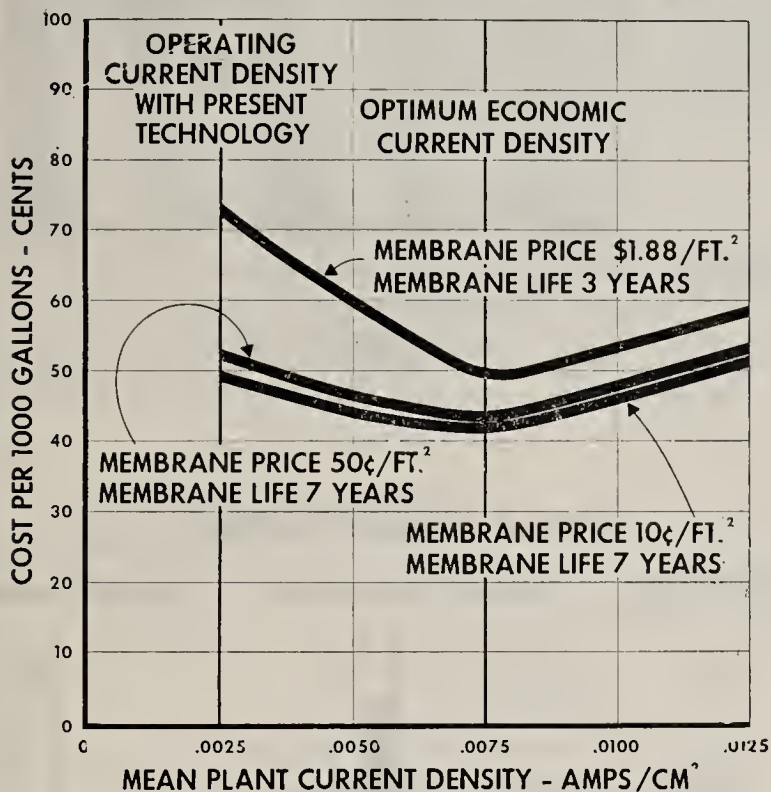


FIGURE 5

EFFECT OF VARYING MEMBRANE PRICE AND LIFE 1,000,000 GPD ELECTRODIALYSIS PLANT



WATER: WEBSTER, SOUTH DAKOTA
LABOR RATE: \$2.25/HOUR
INTEREST RATE: 5 PER CENT
ELECTRICAL RATE: 10 MILS/KWH

FIGURE 6

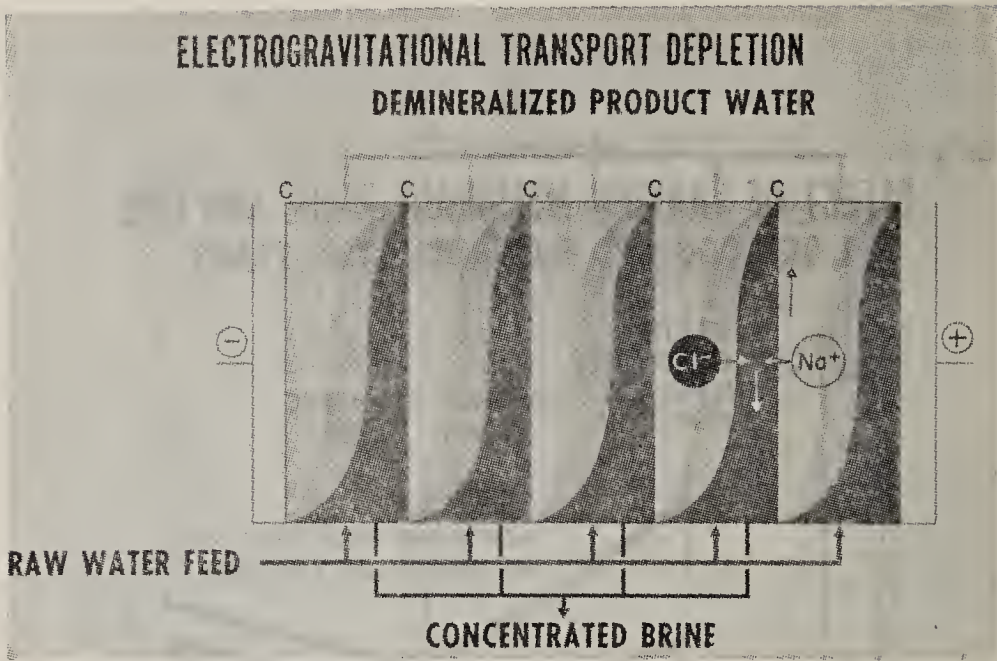


FIGURE 7

REVERSE OSMOSIS PROCESS

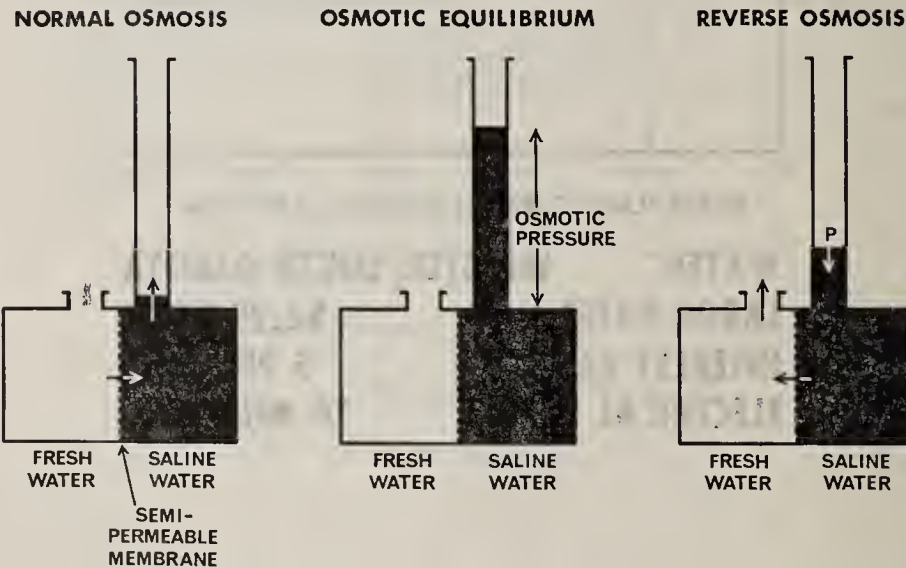


FIGURE 8

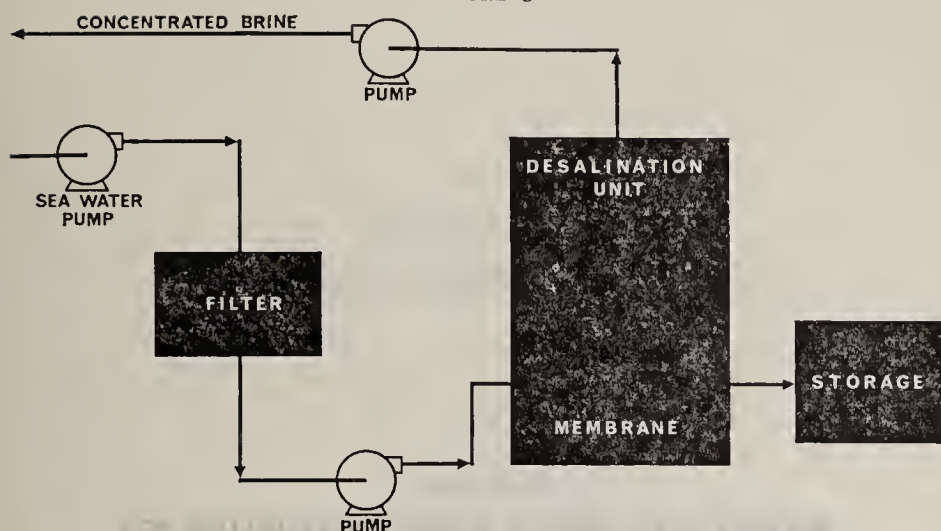


FIGURE 9

LIFETIME OF CELLULOSE ACETATE MEMBRANES

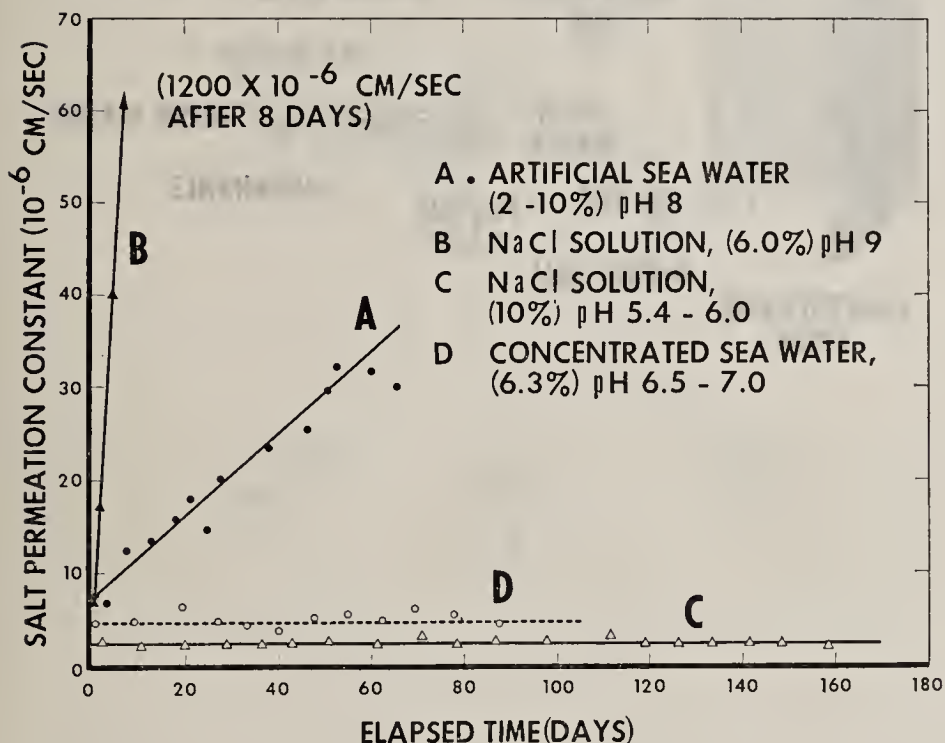


FIGURE 9a
MULTIPLE PLATE REVERSE OSMOSIS DESALINATION CELL

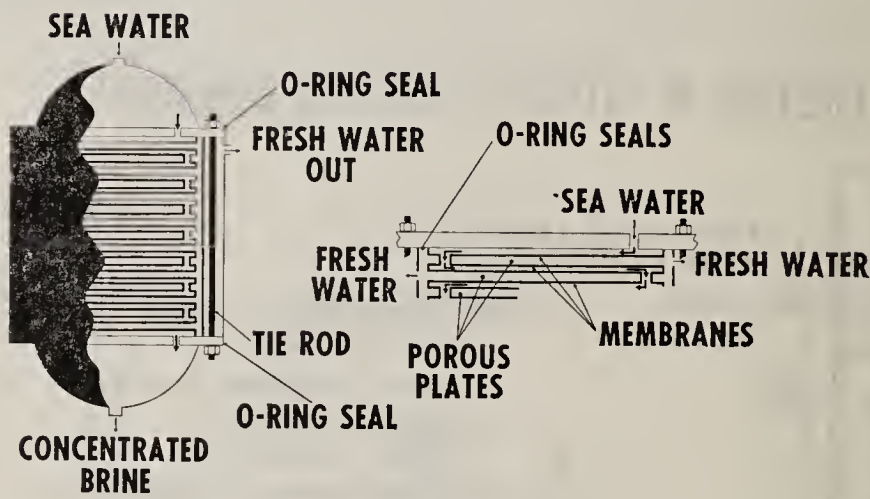


FIGURE 10
**REVERSE OSMOSIS
SPIRAL MEMBRANE MODULE**

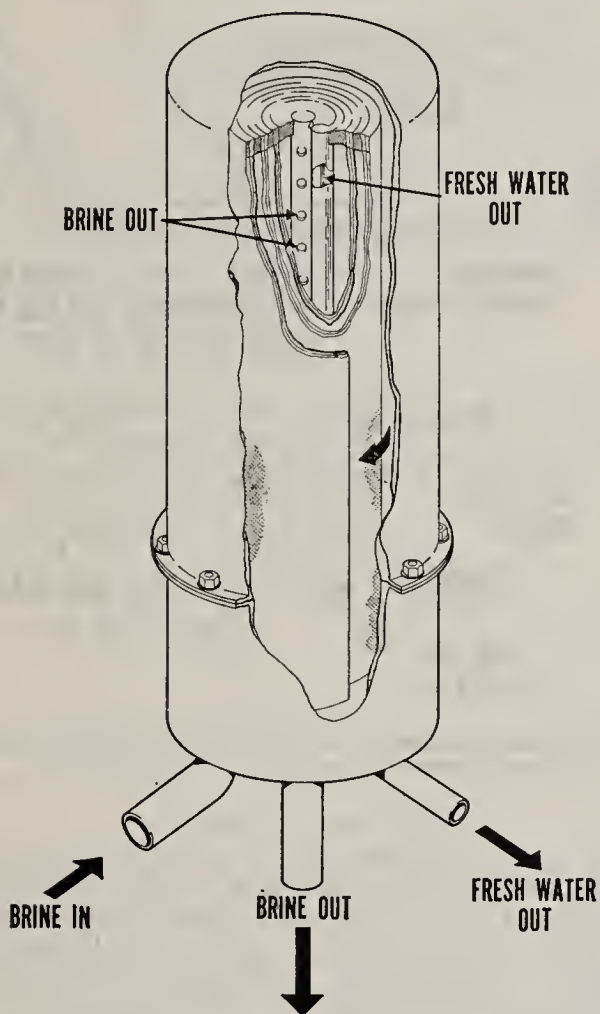
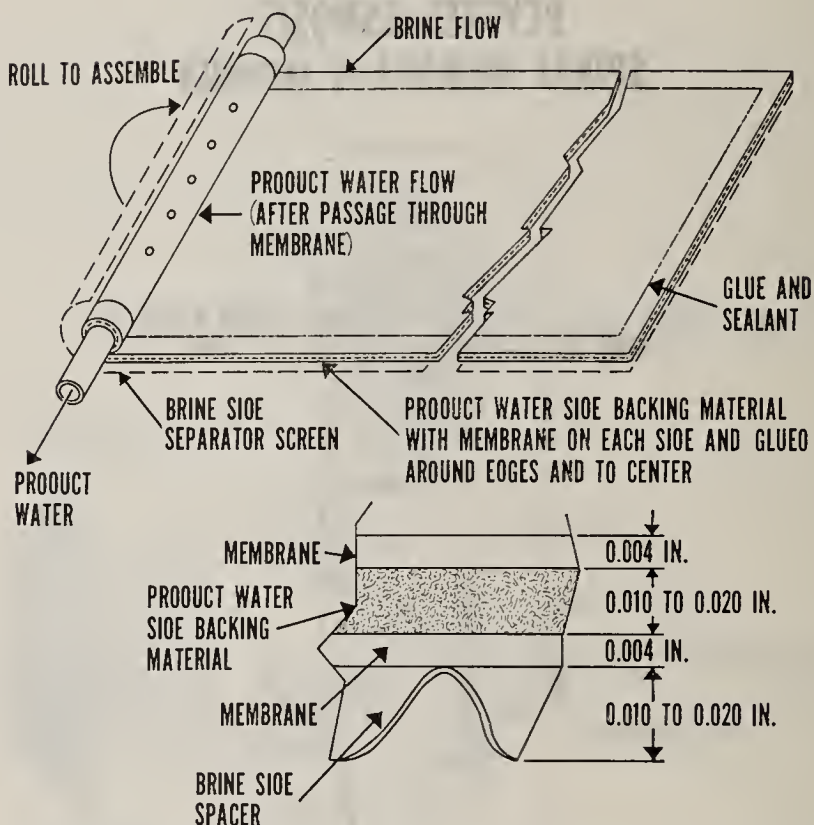


FIGURE 10a

REVERSE OSMOSIS DETAIL OF SPIRAL MEMBRANE CONCEPT



PROPOSED SPECIAL PROJECTS PROGRAM, FISCAL YEARS 1966-72 OF THE DEPARTMENT
OF THE INTERIOR, OFFICE OF SALINE WATER

SPECIAL PROJECTS

Special projects includes applied research, engineering development, testing, and evaluation, with respect to crystallization processes including freezing and hydrates, ion exchange processes, and special research and development projects related to all processes such as equipment components, deaeration, byproducts, water pretreatments, and brine disposal. Developments are undertaken on new promising approaches or new concepts for saline water conversion processes including those stemming from the basic research program which may lead to improved and lower cost conversion techniques than possible through the use of existing processes.

CRYSTALLIZATION

Introduction

The application of refrigeration principles to the desalting of water was reported in the literature as early as 1945. Meaningful efforts in this area of research, however, were initiated in the 1950's with the increasing interest in saline water conversion and because of the potential advantages of freezing over more conventional processes such as distillation. These advantages as

compared to distillation are (1) no scale formation problem, (2) lesser tendency toward corrosion and, (3) a lower energy requirement to bring about conversion. To preserve these advantages, freezing of sea water is brought about by direct methods of refrigeration, thus eliminating the expense of metallic surfaces, and making use of less energy. This can be accomplished by flash evaporation of a portion of precooled sea water under reduced pressure or by vaporizing a refrigerant such as n-butane in direct contact with sea water. In either case the latent heat must be recovered and used to melt the salt-free ice. This is accomplished by compressing and condensing either water vapor or refrigerant vapor on the ice.

In commercial operations it would be necessary to carry out the freezing and wash-separation operations as rapidly as possible and to maintain the bulk of equipment per unit of potable output as low as possible to achieve maximum economy. It was found in early investigations both as the laboratory and bench-scale level that rapid production of ice gave rise to the formation of very small ice crystals. Because of their small size and large number, the ice crystals presented a large surface area to which a large amount of the brine adhered and made the separation of ice-brine mixtures exceedingly difficult. The immediate problem, therefore, facing freezing technology was that of devising an efficient low-cost method of separating ice and brine and/or developing a suitable control method for growing large ice crystals which would facilitate washing.

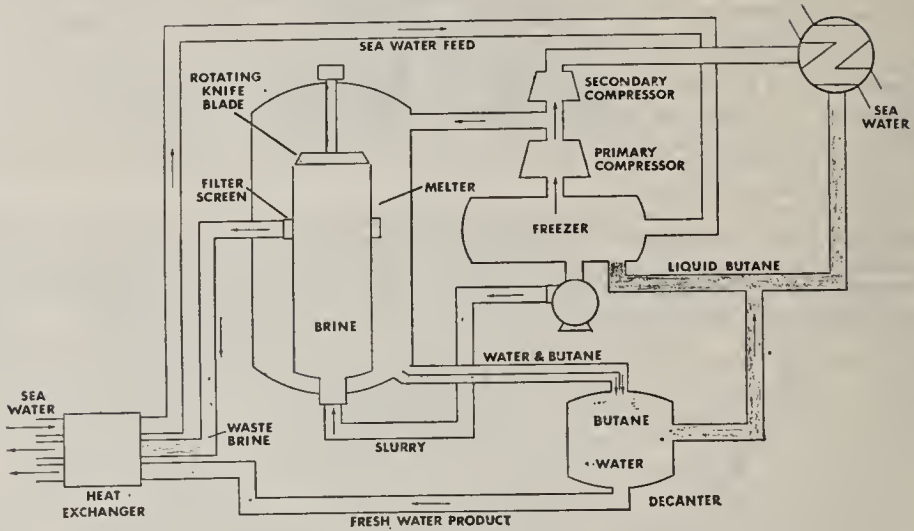
At the present time it appears that the freezing processes will be most advantageous in small- or intermediate-size sea water conversion plants. That is, plants up to 10-million-gallons-per-day capacity of fresh water production. They are also expected to be advantageous in many brackish water applications where usually smaller conversion plants can meet the water requirements. Under these circumstances and applications, lower cost fresh water than obtainable by any other conversion processes can be anticipated.

Secondary refrigerant

In 1958, the Office of Saline Water initiated studies to determine the feasibility of a freezing process in which a hydrocarbon such as butane was flashed in direct contact with sea water. The resulting slurry, consisting of ice and brine of 50-percent-solids content was processed and the washed ice crystals were melted by the condensation of compressed butane vapors. From out of these early studies grew the concept of the wash-separation column which employed the principle of the hydraulic piston in both the separation and washing steps. The process flow sheet is shown in figure 1. Sea water is cooled by reject brine and product water leaving the process. The sea water enters the freezer and is mixed with butane. The evaporation of butane lowers water temperature to freezing point and forms pure ice crystals mixed with brine. The ice-brine slurry is pumped into the bottom of a large column where the ice is compacted into a porous bed. The flow of brine through the pores of the bed (hydraulic piston bed technique) created a positive pressure on the bed propelling it upward. The brine flowed out of the column through screens at a point midway up the column. In the upper portion the ice bed was contacted countercurrently with a stream of fresh water to provide either a flooded or a drained bed and a rotating knife blade positioned at the top of the column cut layers of washed ice off into a chute and thence to a melting vessel. The butane vapor removed from the freezer is compressed and condensed on the washed ice in the melt vessel. Fresh water and liquid butane are pumped to the decanter for separation. Liquid butane is recycled to the freezer. Product water is pumped to distribution. Excess butane vapor is compressed by secondary compressor and condensed in auxiliary condenser. Liquid butane is recycled to the freezer. The principle of washing used in this process evolved from the laboratory to bench-scale level and then to pilot plant sizes of about 35,000 gallons per day capacities. Although this principle of washing is well established, high-efficiency operations and fast throughput are dependent in a large measure on particle size. Thus, to achieve maximum production rates, it was necessary to review earlier freezing concepts in an effort to grow ice crystals of a large size. Subsequent developments in freezer design and ice crystal growth control indicated that a fairly uniform particle size distribution in the range of 0.75- to 1.5-millimeter diameters was required for practical utilization of wash-separation columns.

Improved wash column separation has been successfully demonstrated in a 15,000 gallons per day pilot plant. Centrifugal separation has also been evaluated in the same pilot plant. Further work has been carried out utilizing different freezer designs to obtain better control of particle size.

BUTANE SECONDARY REFRIGERANT PROCESS



The secondary refrigerant method has been successfully employed in a 35,000 gallons per day (design capacity) pilot plant. With improvements in wash-separation column technology rates up to 55,000 gallons per day of potable water have been obtained. This pilot plant has demonstrated reliability as well as uniformity of operations. Improved wash column separation has also been successfully demonstrated in a 15,000 gallons per day pilot plant. Centrifugal separation is also being studied in this plant. An enlarged version of the 15,000 gallons per day pilot plant has been built at Wrightsville Beach and has been designated as the east coast conversion plant. This is a 200,000 gallons per day experimental plant built to meet the requirements for a sea water conversion plant on the east coast, as provided in the Demonstration Plants Act. Mechanical difficulties along with design problems in the various unit operations are being studied in order to permit evaluation of the centrifuges as well as other system components.

More sustained pilot plant runs are needed and will be carried out in our present pilot plants in order to refine the various unit operations to obtain data for extrapolation to large capacity plants.

Examples of refinements that are needed in various unit operations are as follows: Modifications to the present freezer designs need further evaluation. Ice cutting devices require additional developmental work in order to devise an efficient method of removing ice from the column to the melter. Additional work is needed to determine the feasibility of direct contact heat exchangers as an economical method of interchanging heat. Further studies are needed in an effort to improve design features of the process so that heat leaks and other inefficiencies are minimized, thus enhancing the economic potential of the process.

In approaching the new program for special projects, cognizance is taken of these problems and plans are projected to continue operation of existing pilot plants with the view toward establishing basic design features. A test bed plant of less than 5 million gallons per day capacity is projected after completion of pilot plant operations, if developments warrant. On the basis of results obtained from the test bed plant, a prototype plant would be considered a cooperative effort with a water user. Provisions have also been made to implement a development program for components or special hardware which subsequent improvements in freezing technology may dictate. The multi-stage precooler or prefreezer for the secondary refrigerant system would be an example. Other research and development efforts would lend support when needed before the final design of a large freezing plant is undertaken.

Vacuum freezing-flash evaporation

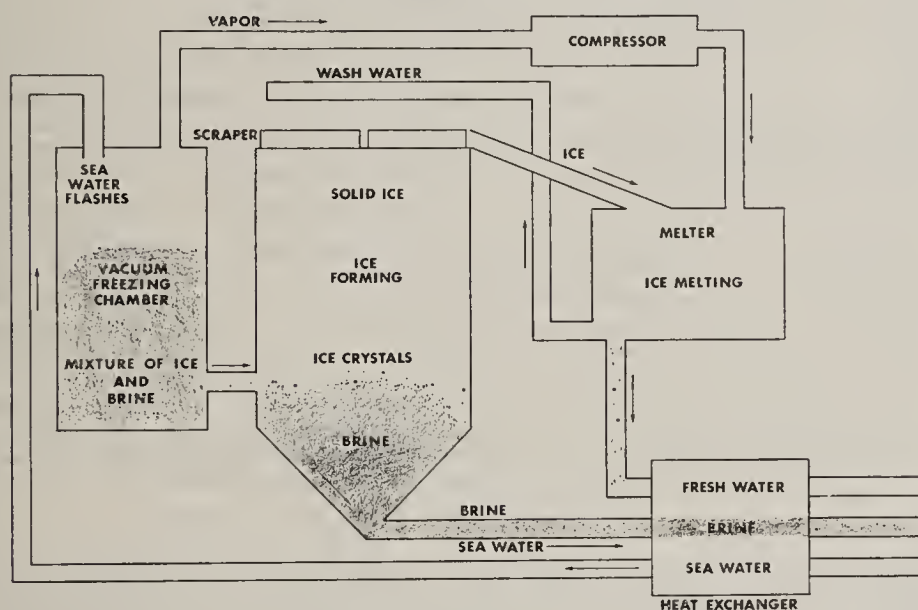
Laboratory evaluation of the vacuum freezing process using an absorption refrigeration cycle was started in June 1956. The successful development of a 300 gallons per day bench-scale model subsequently led to the design and construction of a 15,000 gallons per day pilot plant. From October 1956 to

June 1960, pilot plant studies were made on synthetic sea water after which the plant was relocated at a seacoast location for evaluation on fresh sea water. The pilot plant program was terminated in May 1963. It was shown that in plants in the range of 165,000 to 200,000 gallons per day the process offered possible economies over distillation processes for comparable size plants. The results obtained from this development project established the principle of the hydraulic piston bed displacement technique which has been used in other freezing processes. It was concluded that the use of a vapor compression cycle would give lower costs if low-cost compressors could be developed for handling large volumes of low density water vapor.

A vacuum freezing-vapor compression process has been developed by industry. This process is based on a low-cost, improved radial compressor and a wash-separation column similar to that developed under the saline water conversion program. The process flow is shown in Figure 2. Sea water is cooled by heat interchange with the brine and product. The sea water enters the freezer where 50 percent of the water is converted to ice at a pressure of 3 millimeter hectogram.

The ice-brine slurry is pumped to the wash-separator and the resultant ice bed is propelled upward by the hydraulic piston bed technique as previously described. The ice is washed counter-currently with a portion of the fresh water. The ice is scraped off at the top of the column and conveyed into the melter. The water vapor is removed from the freezer, compressed, and condensed on the washed ice, which results in product water. Development work led to the design of a 60,000 gallons per day pilot plant which was evaluated in Beloit, Wis. On the basis of this plant, a four module desalination plant (240,000 gallons per day) was built and shipped to Israel. This plant is presently operating on an experimental basis and supplying potable water to the city of Eilat. Future work in this area of freezing developments will be the evaluation and further development of the 60,000 gallons per day pilot plant at Wrightsville Beach to determine the maximum capacity of the plant, and especially of the vapor compressor, at a seacoast location. In order to accomplish the goal of increased output, it is necessary to develop information describing the mechanisms through which the various functions within the freezing process take place. Better performance will permit the determination of ultimate output obtainable from a single module. At the same time the process improvements can be incorporated in design parameters for larger single modules in the 1 million to 5 million gallons per day range.

SALINE WATER CONVERSION BY FREEZING



The design and construction of a test bed plant based on vacuum freezing-vapor compression process is planned after completion of pilot studies if results so justify. Actual sizing of the plant will depend on results obtained at Wrightsville Beach. It is believed that the process will show advantages in small size plants either in coastal or inland areas. The latter application may show additional economies when brackish waters of 5,000 to 10,000 parts per million total dissolved solids are used as the feed. This concentration is not too economical for electrodialysis and for many brackish waters not too practical for distillation. The process also offers the advantage of not requiring a hydrocarbon refrigerant, thus there are less safety requirements and no necessity to remove residual hydrocarbon from the product. Brackish waters in certain areas are contaminated with high concentrations of calcium and magnesium sulfates. Since this freezing method is not scale forming, it could have an added advantage in this respect over both distillation and electrodialysis. Later in the program it is anticipated that the vacuum-freeze system could be recommended for prototype plants.

Hydrate processes

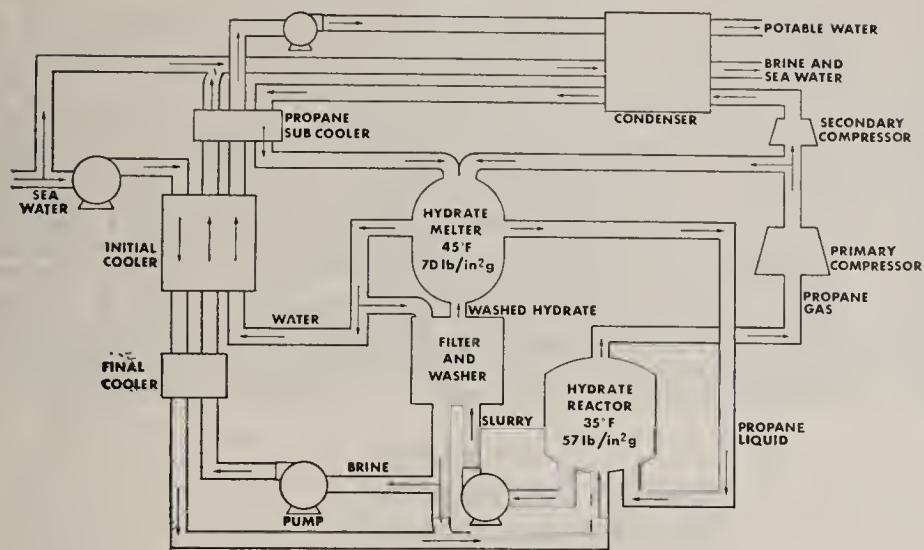
One of the more recent approaches to saline water conversion is that of chemically separating pure water from salt solution by the use of hydrate-forming materials. It has long been known that certain compounds such as low molecular weight hydrocarbons or their halogen derivatives combine with water to form solid clathrate compounds which are inclusion complexes in which molecules of one substance are contained or enclosed within the crystal lattice of another component. Like ice crystals, clathrates reject ionic constituents and accept only pure water molecules in their lattice. The crystals are separated from the mother liquor by either filtration, column washing employing the hydraulic piston bed technique, or cyclone separation, then washed free of mother liquor and decomposed into two immiscible liquids; liquid hydrating agent which is recycled and salt-free water. The process flow for the hydrate system is shown in figure 3.

Sea water feed is heat exchanged against product water and reject brine streams. It then enters the reactor where it is mixed with liquid propane at 35° F and 57 pounds per square inch gage. Propane hydrate crystals form as a solid phase. The propane serves both as hydrate former and a second refrigerant to control the reaction temperature. The hydrate-brine slurry is pumped to a filter-washer where hydrate is separated from the mother liquor and then pumped to the melter. Liquid propane from the melter is recycled to the reactor. Propane vapor from the reactor is compressed and condensed on the washed hydrate crystals to effect decomposition to liquid propane and fresh water. Excess propane vapor which does not condense on the hydrate crystals is removed and compressed by a secondary compressor. The vapor is then condensed by heat interchange with sea water, potable water, and waste brine streams. From the melter a portion of the fresh water is cycled to the washer to wash the hydrate crystals and the remainder is sent to storage after heat exchange with the incoming sea water stream. A portion of the reject brine is recycled to the reactor to control viscosity of the reaction mixture while the remainder is heat exchanged against incoming sea water and then discarded.

Like freezing, the hydrate has several potential advantages over other methods of desalination. It is similar to freezing in that the separation of water involves the formation of an insoluble phase which must be washed free of brine. Since the hydrate process is operable over a range of moderate temperatures, depending on the hydrating agent used, problems of scale and corrosion are minimized. From the standpoint of energy considerations, the hydrate process has an advantage over freezing. For example, in pure water ice exists at 0° C, where as propane hydrate exists at 5.7° C. This difference of 5.7° C is also maintained in salt solutions irrespective of concentration. Thus, the propane hydrate process, operating at temperatures above those employed in freezing, offers the potential advantages of lower energy requirement and investment costs.

In 1959 the Office of Saline Water supported, under a cooperative contract, the development of a hydrate process based on a patented process. Most of the work was carried out in bench-scale equipment including a 10-gallon reactor-crystallizer with a capacity equivalent to 150 gallons of potable water per 24 hours. In addition, laboratory research was done on the hydrate forming reaction and calculations were made to evaluate the processing steps and to determine the order-of-magnitude of the production costs. In this process, two

PROPANE HYDRATE PROCESS



methods of washing the hydrate crystals have been investigated at the bench-scale level. These methods are (1) filtration and (2) column washing using the hydraulic piston bed technique.

In view of the promising bench-scale work, a 10,000-gallons-per-day pilot plant to evaluate this process is being built. Scaled down experiments will be conducted in the pilot plant on the two different methods of wash separation in order to determine which method will be used for additional pilot plant studies. The pilot plant is expected to be completed approximately September 1965.

Also being investigated is another hydrate process which employs cyclones for washing the hydrate crystals and which is based on a different patented version with potential advantages. This process had an initial development by industry in a small 700-gallons-per-day pilot plant. In May 1962 this Office supported the further development of this process in this 700-gallons-per-day pilot plant. The results of the investigation indicated considerable promise.

In order to further develop the process, this Office supported through contract the design and construction of a 20,000-gallons-per-day pilot plant at the Research and Development Test Station, Wrightsville Beach, N.C. Operational evaluation of the pilot plant was started in April.

The hydrate processes, using propane as the hydrate former, are less further advanced than freezing processes. Although problems similar to those experienced in freezing studies will undoubtedly arise, it is expected that the technology will move ahead more rapidly because solutions to freezing problems will in part be applicable to hydrates.

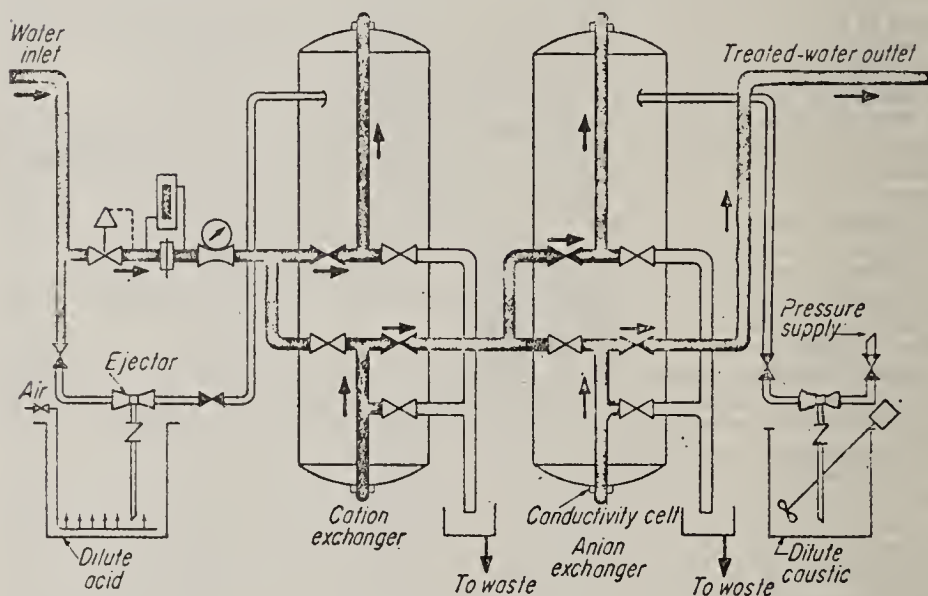
The projection of test bed plants must await the results from pilot unit operations. However, if breakthroughs are possible within the next year, it may well be that hydrate will advance faster than freezing. The use of cyclones as a wash-separation device may provide a means for increasing capacities with no large increase in equipment size. Then too the use of filtration or column separators may also work to a greater advantage with hydrates than with freezing. The hydrate system may require further research and development support particularly in component development and design. However, it is somewhat early to pinpoint any specific problems at this time. The results of pilot plant operations will define more clearly the problem areas, and the justification for further development effort.

ION EXCHANGE PROCESSES

Ion exchange processes pass saline water through an ion exchange material. See figure 4 for typical ion exchange flow sheet. This material has the ability to exchange one ion for another, hold it temporarily in chemical combination, and give it up to a strong regenerating solution. Salt can thus be removed from

saline water. Ion exchange desalination has been used effectively to obtain small quantities of fresh water from sea water in special applications, such as emergency kits for liferafts. A few Department of Defense installations, such as radar warning stations, have successfully used ion exchange desalination for producing limited quantities of potable water from brackish water. Also, ion exchange demineralization has shown advantages for obtaining fresh water of comparatively low dissolved solids for special industrial and other uses. Ion exchange processes have been too costly to consider for desalination of appreciable quantities of sea water or highly brackish water. However, in recent months there has been an announcement of several developments by commercial firms which make use of newly developed ion exchange resins together with new approaches to regeneration of the resins, which may make ion exchange desalination less costly than electrodialysis in certain locations when applied to waters up to 3,000 p.p.m. (parts per million) total dissolved solids. Thus, a test bed plant (500,000 g.p.d. (gallons per day) or two 250,000 g.p.d.) should be ready for construction within several years. New approaches or any additional development will also be considered. Ion exchange processes may be adaptable in certain locations to treating polluted waters, such as acid mine waters.

FIGURE 4
Typical Ion Exchange
Desalination Process



BRINE DISPOSAL

Brine disposal at coastal locations became much more of a problem when current plans for large sea water conversion plants were adopted. Disposal of waste brines from inland areas has been recognized as a problem for sometime but has not yet been satisfactorily solved although preliminary investigations have been conducted. The proposed program on brine disposal includes research and development studies to determine the effects of brine disposal factors on aquatic environment, and inland areas. Environmental studies will be undertaken in the laboratory and in the field. They will include engineering and cost studies relating to submerged offshore piping, subsurface injection, ponding, solar evaporation, and other possible means of brine disposal or use (e.g. by-products).

PRETREATMENT AND BYPRODUCTS

The pretreatment of saline water feeds prior to conversion processing is an effective means of reducing scaling problems, particularly in distillation systems. Chemical pretreatments also make possible the production of useful byproducts from sea water, such as certain potassium and magnesium compounds. Experimentations with actual conversion plants both in the pilot plant and demonstration plant operations have shown that filtering is needed to remove suspended materials, organic materials of various types, and other materials detrimental to processing. More study and evaluation will be undertaken to determine the most suitable type and adaptations of conventional filtering and pretreatments to problems of saline water conversion.

A pilot plant is now operating at the research and development test station to obtain data on several chemical pretreatment methods, as well as several byproduct recovery methods. Ion exchange pretreatments to soften sea water were developed in pilot plant size; they can be used now in conversion plants although further improvements are being made. A method of this type was incorporated in the Roswell demonstration plant and is now being tested and evaluated.

Concentrated brines which are waste products from conversion plants may also be sources of useful byproducts. Studies of this possibility have in recent years been more favorable because through various process improvements in distillation it is now possible to obtain higher waste brine concentrations than previously, and also because of the concept of large plants. However, a word of caution is necessary in that economical recovery of byproducts, either from the chemical pretreatment process or from a process which treats the waste brine, is dependent upon market conditions, size and location of plant, type of conversion process, etc.

POLLUTION

As used in the act under which the Office of Saline Water operates, the term "saline water" includes sea water, brackish water, and other mineralized or chemically charged water. Some polluted waters will require desalination processes, either separately or jointly with processes being developed by HEW to treat polluted waters per se. Acid mine waters, in certain cases, might be treated by some desalination process. More research and development on pollution problems is needed. Contributions to the state of the art (prototype plant) in pollution abatement or control, including acid mine water drainage problems, is anticipated at the time new approaches to these problems become developed far enough for practical applications by user organizations.

Mr. ROGERS. I think we will meet in the morning at 9:45.

Our first witness at that time, I think, is Dr. Hornig.

The subcommittee will stand adjourned until 9:45 in the morning.

(Whereupon, at 5:45 p.m., the subcommittee adjourned, to reconvene at 9:45 a.m., Friday, May 21, 1965.)

TO EXPAND, EXTEND, AND ACCELERATE THE SALINE WATER CONVERSION PROGRAM, CONDUCTED BY THE SECRETARY OF THE INTERIOR

FRIDAY, MAY 21, 1965

HOUSE OF REPRESENTATIVES, SUBCOMMITTEE ON
IRRIGATION AND RECLAMATION OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:55 a.m., in room 1324 Longworth House Office Building, the Honorable Walter Rogers (chairman of the subcommittee) presiding.

Mr. ROGERS. The Subcommittee on Irrigation and Reclamation will come to order for the further consideration of the pending business, to wit, H.R. 7092 by Mr. Aspinall, of Colorado, to expand, extend and accelerate the saline water conversion program conducted by the Secretary of Interior and for other purposes.

Our first witness this morning is Dr. Donald H. Hornig, Director of the Office of Science and Technology and the Science Adviser to the President.

Dr. Hornig, it is nice to have you here and you may bring with you to the witness stand such aids as you desire.

STATEMENT OF DR. DONALD F. HORNIG, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY

Dr. HORNIG. Mr. Chairman, members of the committee, it is a pleasure to appear before the committee this morning and to share with you some of my views concerning our program for the desalting of water. I shall not dwell on the need for new sources of fresh water. In his message transmitting proposed legislation to extend the research program in desalting, the President clearly stated the need for developing new sources of fresh water at costs which are competitive with those to be expected from the sources we have been tapping.

There are, of course, a variety of needs ranging from the large-scale production of agricultural water at costs under 5 cents per thousand gallons (\$15 per acre-foot), a goal to which we cannot yet see a solution, to the large-scale production of municipal and industrial water supplies at 25 or 35 cents per thousand gallons, the goal to which the present program is predominantly addressed. A separate problem and a great need is for much smaller scale water supplies for the many communities in the midcontinent depending upon brackish ground water at prices which in some circumstances may range as high as \$1.50 or \$2 per thousand gallons.

Impetus for the proposed new program has arisen to a considerable extent from a report prepared by an interagency task group for the Office of Science and Technology in March 1964. This report assessed the suggestion of AEC scientists that very large-scale nuclear-powered sea water distillation was economic.

After going over the problem in considerable detail, the task force concluded that, depending on the basis of financing, dual-purpose plants using current distillation technology, producing electric power as well as water, when scaled up to capacities approaching 500 million gallons of water per day and 500 megawatts of electric power might be expected to yield water at costs between 25 and 35 cents per thousand gallons (\$75 to \$105 per acre-foot).

A process such as envisioned in the report might well be competitive now for the production of M. & I. water. However, it would involve construction of plants more than 100 times as big as any yet built. This involves formidable engineering problems and the central thrust of the new program is to pursue the engineering development leading to such plants, and if possible to reduce the cost of water below the levels envisioned in the report. Of course, the number of localities in this country at which such volumes of M. & I. water and such electric power levels can be simultaneously consumed is limited. To broaden the benefits of the program it is most important to find ways of reducing costs well below those that can be obtained by a simple scale up of the current state of the art so as to provide economically competitive water in smaller plant sizes, perhaps 50 to 100 million gallons per day.

If we are to reach this goal, we will have to undertake a program of intensive research on new materials and simplified processes which will reduce the capital investment in such plants and the requirements for heat.

The proposed bill authorizes the funding of such a program. In order to cut costs and devise more effective processes, we need to know many things. We need to know more about corrosion of the many materials available for use and more about the physical chemistry of salt solutions. We must improve the rates of heat transfer within the process.

We must understand the process of scale formation in order to find cheaper ways of preventing it. We must develop better and cheaper materials to use in desalting plants. These are only a few of the questions that must be explored. These and related studies will involve scientists in industry, government, universities, and research institutes. Much of the work will necessarily begin in the laboratory and, indeed, work on these questions and others has been underway in laboratories all over the country for some time. It is probable that no single breakthrough will mark the first major success, but rather a combination of many scientific advances and substantial amounts of engineering ingenuity.

However, laboratory work alone will not suffice. To reach a practical goal at an early time will require that the results of laboratory research be tested through the construction of pilot units using new methods and concepts. From pilot plants we must move to construction of modules which are segments of large-scale plants but not in themselves complete or economic production facilities. The modules

permit exploration of engineering techniques on a larger scale than is possible in the pilot plants.

The next stage, and one which ought to be undertaken as early as possible, is the construction of a prototype plant. A word may be in order as to what I mean by a prototype plant. A prototype plant is a full-scale production facility which is a first module of later operational facilities. It should utilize the most advanced technology available at the time it is constructed. Indeed, it should stretch our technology to the limit, for only through this stretching can a prototype plant serve as a stepping stone to truly efficient and reliable operational plants. A prototype plant should be distinguished from a demonstration plant. If we move too early to plants which demonstrate what can be done operationally, we will not be pushing forward satisfactorily toward meeting the ultimate goals. For this reason, a prototype plant need not itself be economic; it should teach us how to build an economic operational plant.

The proper definition of the first prototype plant should properly depend on both the results of the R. & D. program and on the estimates and conceptual studies produced by our advanced engineering and industrial firms.

In my opening remarks, I stated that water costs from natural sources now range from less than 5 cents to over \$2 per thousand gallons. Thus, when we use the words "competitive cost," they have no unique meaning. A plant producing water at \$1 per thousand gallons might be competitive with conventional supplies in one locality, but this cost could be outrageously high for another area more favorably located with respect to water resources or with a larger demand.

Present technology is, therefore, capable of meeting immediate needs in some specific problem areas where current water costs are high or where adequate fresh water is unavailable, regardless of cost. Industry has been supplying desalting plants in such locations for some years and is continuing to do so. These plants have generally had capacities of less than a million gallons per day, but have ranged up to as high as 2.5 million gallons per day.

It is not yet clear whether industry can, in the immediate future, adapt current technology to the design of plants which will produce competitive water in areas where the cost of conventional water supplies is relatively low. The large-scale industrial interest in the desalting effort and the conceptual studies which are being undertaken by many firms have increased the effort devoted to the problem and brought a force of ingenious men into the field. It is possible, as has occurred often in the past on other problems, that when imaginative men get to work on a problem we will see that workable and economic plants can be designed right now, even before much development has gone forward. However, the promises and designs will have to be verified. We have had much experience in military research and development with promises which outstrip the ability to perform, and paper gains which have gone under the name of "brochuremanship."

At this point I would like to interpolate a little in my prepared comments to note that the committee will certainly hear many estimates of costs as the hearings go forward, and these costs in general are not entirely comparable. One should be clear on cost esti-

mates, what financing basis is assumed, and what charges are made for the heat input. For any given design, I can vary the projected cost quite a lot by the nature of what I charge you for the heat that goes into the plant. So that basis of costs must be carefully assessed.

It is for this reason that we must press both an R. & D. program and the industrial design effort. By either route it is clear that we will need to build a prototype plant on a suitable scale at an early point in time if we are to get our feet on the ground and see where we stand. The fact that industry may already be able to provide plants which are acceptable in some locations or for some users does not signal the end of the problem. We must be looking toward second and third generation plants.

The main thrust of the new program, as I have mentioned, is toward very large scale distillation plants. A quite separate problem is that of the small plant (a few million gallons per day or less). Such small plants are needed to process brackish ground water in the central and western interior of the country. It is unlikely that the distillation processes can be sufficiently economic for this purpose, but the various membrane processes hold enormous potential for the future. Much research on the properties and fabrication of membranes and their practical application will be necessary before truly low-cost water is possible. One of the complicating features of research on desalting brackish and waste waters is the wide diversity in the chemical composition of these waters. A process which is highly successful in one application may encounter serious difficulties in others. This is not an insurmountable obstacle but simply another variation to be coped with.

The membrane processes may also prove useful in processing waste water from industries and municipalities for reuse. Some 60 billion gallons of such waste waters are produced daily. They contain from a few hundred to perhaps 2,000 parts per million of salts. These waters, because they are already at centers of use, may be reclaimed at costs competitive with the cost of producing "new" water in many instances.

In the long run it seems likely that membrane processes can be developed to the point where they will become the most efficient means of desalting sea water. This possibility is certainly not practicable now, but the membrane research which is currently aimed at small scale plants is likely to provide the technological base for future generations of large-scale plants.

The great dream of the future is to provide desalted water for agriculture. Such a goal is not in sight. We cannot even promise its attainment in the near future for extremely high value crops. Nevertheless, the goal is not theoretically impossible. It may even be possible to achieve selected removal of salts so that desirable salts can be retained and undesirable ones rejected. We will not reach these goals—indeed we will not even know whether we can reach them—if we do not move forward with the next phase of desalting research through the program which has been proposed by this administration.

Mr. ROGERS. Thank you, Mr. Hornig.

Mr. Aspinall.

Mr. ASPINALL. Mr. Chairman; Dr. Hornig, of course, no one can take exception to what you placed in the statement. It is a very inclusive statement, but I think you can put practically the whole universe in what you have evolved here, could you not? This is what bothers me as a practical legislator trying to represent our people who do have a limit to the amount of cooperation that they can give to a program. What is your personal feeling, Dr. Hornig, as to where Government should stop in its operations in research and should turn over under our form of government the continuance of programs to private enterprise?

Dr. HORNIG. At the stage, I would say, where the private industry can see a big enough market so it is willing to invest adequate R. & D. funds to go on with the program. I think then it is appropriate to leave it to the private sector.

Mr. ASPINALL. Are you favorable to some of these large private enterprise groups who are engaged in many different undertakings so that they make sufficient profits on some of their undertakings to permit them to spend money for research and development in other areas as they see fit—are you favorable to their participating in the research work?

Dr. HORNIG. I do not see how to answer this question generally. In all of the industrial enterprises I know, if they foresee a big enough market, they will spend quite a lot on the background research necessary to go on and make substantial advances. If they do not see enough of a market to pay off they won't do so.

Mr. ASPINALL. You do not mean to tell me that the private enterprise groups such as Du Pont, General Dynamics and all the rest such as General Electric, are not spending millions of dollars a year on research matters on which they do not have any definitive answers as far as making profits are concerned.

Dr. HORNIG. All of the biggest and best industrial laboratories I know do carry on a certain amount of general background research. But in all of them, the majority of their work is focused on the problems in which they are immediately or prospectively engaged. This is true not only in desalting, but I think generally the proper role of the government is to carry on that general background or basic research and technological development which is diffuse and of value to every industrial supplier and which will not provide a specific answer to any particular one.

What I have in mind in this area, is that all of the industrial laboratories carry on work, for instance, on corrosion. But corrosion is a very big topic on which we have been working all of this century and I am sure will be working through the rest of the century. Most of their work on corrosion will be devoted to the specific materials they propose to incorporate in plants that they design.

In the background is the question of how to choose materials, how to find new materials. There are in any given plant a great variety of materials of construction. So that in order to make the right choices we have to have a general background of knowledge about the corrosion of various materials by various solutions under many circumstances. It is this sort of background information that is what is developed in universities and places other than in the laboratories of the people designing the plant.

MR. ASPINALL. Let me ask the question another way. Which do you think is the most effective driving force in order to find the answers to some of the problems that perplex us today and to find the facilities which we are going to need in the future—the profit which comes from labors performed and industriously carried on, or work that is done because people are dedicated to ideas. Where do you get your result? I would like to know that.

DR. HORNIG. We need both, I think.

MR. ASPINALL. If you will admit that, then we won't go any further. Is there any limit in your opinion, Dr. Hornig, to what man should try to do to change nature or make nature do something which nature does not at this time succeed in doing?

DR. HORNIG. That is a very philosophical question.

MR. ASPINALL. No, it is not, it is a practical question. Because the money of the taxpayers of the United States is involved here. This is the reason I ask you the question. If we could give you folks downtown all the money you want to do the things you think are good, and we might agree with you, I think this would be wonderful. But we have to make decisions some place and cut here and there. We are going to the moon. We are making water. We are doing all of these things. Where is the limit to what we should undertake?

DR. HORNIG. I think as a general matter there is no limit to what we should do to change nature as long as it is beneficial and as long as the yields to the Nation and to the people well exceed the expense of doing it. I think it is economically demonstrable that most of the R. & D. we have done in the past on most topics has paid off enormously. We have not gone far enough in this field to have a ratio of benefit to cost. In agriculture it is demonstrable that it is a 700-percent yield.

MR. ASPINALL. You hit my next question before I got to it. I want to know, have you evaluated what we have gotten from this program on which we have spent approximately \$50 million.

DR. HORNIG. Most research work does not really pay off for 10 or 20 years. So we are not far enough downstream to perform a good cost-benefit analysis. I think we have gotten \$50 million worth of value but I cannot demonstrate it in numbers.

MR. ASPINALL. I won't press it any further. You say in your statement right at the very beginning that the President clearly stated the need for developing new sources of fresh water. Of course, hundreds and thousands and tens of thousands of other individuals in the United States have worked on this matter long before this administration came into existence. We do not need the administration especially telling us what to do. We need the administration telling us what it thinks is worthwhile to do and how it is going to be done. In your statement you indicated that many figures will be used to substantiate the positions taken. Yet in your own statement, you say that water costs from natural sources now range from less than 5 cents to over \$2 per thousand gallons.

We all have to agree to this. This shows that you can take figures and use them in such a way as to prove a point just like some of our other witnesses will here this morning. Isn't that true?

DR. HORNIG. No, the range I am speaking of here is not calculational. The 5 cents applies to water taken from river sources and conven-

tionally for irrigation. The \$2 or even bigger numbers applies to water taken from water-scarce areas, frequently from wells or similar sources.

Mr. ASPINALL. What percentage of the present budget, that is, 1965, which ends this June, for water resources research goes for research in desalting.

Dr. HORNIG. I think the number for water resources research is approximately \$100 million as a total. So this would make it about one-fifth.

Mr. ASPINALL. Does your office participate in the allocation of budget funds to the various research programs?

Dr. HORNIG. Yes, indeed it does.

Mr. ASPINALL. The water research budget for fiscal year 1966, page 459, of the little budget book, shows an increase from \$75.3 million to \$100.5 million, about 35 percent. Aside from the funds for the water resources research centers at the land-grant institutions, most of the increase appears to be in the saline water conversion program. If the legislation now before the committee is approved, an additional increase in the desalting research program will be authorized. Does this imply that you think that desalting is the most important water research field at the present time?

Dr. HORNIG. It implies that we think that at the present time it is economic and fruitful and has been identified and studied carefully. We are carrying on work and analyses on other areas of water research. The Department of HEW is much concerned with water reuse. We have studied that. So I think other programs will come forward as they are found to be profitable.

Mr. ASPINALL. Isn't it true, Dr. Hornig, that right at the present time more water is recoverable at less cost from these lesser polluted waters that we find in our rivers than from desalting procedures?

Dr. HORNIG. Yes, but the water is not always in the right place.

Mr. ASPINALL. I understand that. It is not quite as glamorous to do that kind of a job as it is to carry on a desalting program, is it?

Dr. HORNIG. I think they ought both to be done. I think in the Los Angeles area there is a considerable amount of water discharged into the Pacific Ocean after one use that ought to be reclaimed and re-used.

Mr. ASPINALL. What percentage of the water research budget do you believe is the optimum for application to desalting research?

Dr. HORNIG. I suppose I would have to say as of the time we made that budget it expresses what we believed was the proper proportion.

Mr. ASPINALL. You tell this committee, then—this is a kind of a tough question and if you do not want to answer it, you do not have to—you tell this committee that the thought behind the recommendations in the budget had to do solely with the question of the values that would be obtained from the money spent.

Dr. HORNIG. I would say that one simply cannot proceed at all times with an optimum balance, that what we believe is that this money would be fruitfully spent. The returns would adequately justify it.

We do not know at this time any better ways to spend the money, but there are many areas related to water resources that have not been thought through adequately yet. So there may well be in the future other ways that proportion might change.

Mr. ASPINALL. I yield to my friend from California.

Mr. HOSMER. I was going to ask the chairman, he keeps talking about this one-fifth of \$100 million to be spent on water resources research involving desalting, we could get a better feel if we could find out what the other \$80 million is going into. I wonder if you might not have him outline that.

Mr. ASPINALL. If the doctor has it there, I think he can give it to us very easily. All I am trying to do is to find out from the doctor who represents the administration and the importance that he thinks should be placed on this particular program as compared to the other program. Do you have the other program there, Dr. Hornig?

Dr. HORNIG. I have the budget table. The items are flood control, hydropower, navigation.

Mr. HOSMER. How much do we have for flood control?

Dr. HORNIG. \$302,000. Hydroelectric power, \$205,000.

Mr. HOSMER. \$205,000.

Mr. ASPINALL. I think you have the wrong table there. What is really involved in the question that the gentleman from California is asking is that approximately \$450 million at the present time is being spent on water research programs. Approximately \$100 million for the next fiscal year is for direct water research programs, as I understand, related to these fundamentals, of which amount about \$23 or \$24 million is for desalting purposes. Isn't that right, Mr. McFarland?

Mr. McFARLAND. That is about right, sir.

Mr. HOSMER. What I would like to know, Dr. Hornig, is where is the other \$77 or \$76 million going in research on water resources, so we get a feel for the allocation between desalting research and whatever else you are doing.

Dr. HORNIG. Let me sort out just the big items to get that in the picture. Fish and wildlife is \$4.6 million.

Mr. HOSMER. Fish and wildlife.

Dr. HORNIG. Yes.

Mr. ASPINALL. Are we doing research on water to take care of fish and wildlife?

Dr. HORNIG. The answer is "Yes." Effects of pollution on water uses is \$3.4 million. Interaction of wastes is \$2.1 million.

Mr. HOSMER. I could not understand what you said.

Dr. HORNIG. The effects of pollution on water uses, \$3.4 million.

Mr. HOSMER. What is the next one?

Dr. HORNIG. The item is interactions of wastes.

The problem of waste disposal. That is the \$2.1 million. Disposal of waste effluents is \$2.5 million. Water quality characteristics, \$1.3 million. Advanced waste treatment, \$1.7 million. Improved waste treatment, \$1.4 million. I am just picking items over a million now. The economics of development and management, \$2.3 million.

Mr. HOSMER. What was that one?

Dr. HORNIG. The economics of development and water management.

Mr. HOSMER. What is that?

Dr. HORNIG. I am afraid I am not prepared this morning to break that one down in detail.

Mr. HOSMER. What is the sum?

Dr. HORNIG. \$2.3 million.

Mr. HOSMER. Is that it?

Dr. HORNIG. Engineering design, this is just a general item, is \$2.2 million; construction, operation, and maintenance is \$2.5 million.

Mr. HOSMER. Of what?

Dr. HORNIG. I would have to go back on this. I am afraid I would have to come back to you and break those items down for you.

Mr. HOSMER. You have about \$35 million so far.

Dr. HORNIG. Yes.

Mr. HOSMER. There are \$76 or \$77 million to account for.

Dr. HORNIG. That is because I did not read the ones under a million of which there is a long list.

Mr. HOSMER. You mean a lot of little research contracts?

Dr. HORNIG. No, it is just broken down in the budget analysis into about 60 items which are not research contracts but are different categories.

Mr. HOSMER. Could you submit us something that somebody could understand?

Dr. HORNIG. I would be delighted.

Mr. HOSMER. As to where these moneys are going and to what agency and for what purpose.

Dr. HORNIG. Yes.

I would like to call your attention to the book called "Federal Water Resources Research Program for Fiscal Year 1965" which is an analysis of last year's expenditures both in substance and in dollars.

I could perhaps summarize that for you.

Mr. HOSMER. You are indulging in brochuremanship.

Dr. HORNIG. No. I want to point out that this is the first attempt and the first year in which we have attempted to answer Mr. Aspinall's question and yours, which is to look at the totality of the program.

Mr. HOSMER. It doesn't make much sense when you say we are spending \$100 million and that is the exact category it ought to be, because that is the way our figures come out.

As a consequence, we would be interested in seeing upon what you base your figures.

Dr. HORNIG. I will be glad to send you a summary.

Mr. ASPINALL. Does your office seek the advice of nongovernmental experts in connection with your review of Government research programs and if so, have they had any comments on the scale proposed for desalting research?

Dr. HORNIG. The answer to the first question is yes. I have a very good panel of completely nongovernmental people who have just begun to look over the entire Federal water resources research program.

With respect to desalting, we have not studied it with an outside panel yet. I have talked to industrial people, people outside of the Government and in a general way, I have heard no sharp complaints as to the magnitude of the proposed program.

Mr. ASPINALL. Does the National Academy of Science's report on water resources recommend an increase in the desalting research program, or is it silent, as far as the matter of funds is concerned?

Mr. HORNIG. I am sorry, I cannot answer that question.

Mr. ASPINALL. I can't find anything in here as to whether or not there is a definite feeling about the necessity of more money.

It was reported a few days ago that you said the Commission should construct large-scale prototypes of desalting plants of 50 to 100 million gallons a day to advance the desalting program.

Is this a correct interpretation of your views? How much would such a project cost, and have you gone into that part, and do you believe the projects should be constructed at Federal expense?

Dr. HORNIG. This is a simple misquotation. I am not aware of any such statement. It is certainly not my view in that form. I can only think that I am misquoted in the statement in my testimony this morning, that 500 million gallons was bigger than could be used in most localities, and that we had to move in the direction of smaller scale plants, say in the 50 to 100 million gallon region, but I stated quite explicitly that the size of the first plant to be constructed should be decided on the basis of studies which are now being conducted.

Mr. ASPINALL. You didn't make the statement? If not, my source is wrong.

Mr. HOSMER. Dr. Hornig, in view of all the agricultural surpluses that we have, why do we need to be thinking about developing water cheap enough to grow more crops?

Dr. HORNIG. None of the present programs have in them the potentiality of growing crops because, as I have mentioned, what is in sight is too expensive. However, in the longer term, our population is still growing and our agricultural surplus is not so great that we can cope with the projected population of this country by the year 2000 without increasing our agricultural production.

Mr. HOSMER. By that do you mean to infer that the desalting of water is the only alternative approach to equalizing the agricultural production of the Nation to consumption demands?

Dr. HORNIG. Not by any means. In many localities there are much cheaper ways to get water.

Mr. HOSMER. No, I am talking about other ways to raise agricultural production for the population. It might also involve more fertilizers and more effective use of agricultural lands in other ways? Are there not other alternative ways of going about this?

Dr. HORNIG. That is correct, and that is why we carry on a big agricultural research program.

Mr. HOSMER. You don't wish to imply then that the future status of the Nation's stomach depends upon the desalting program?

Dr. HORNIG. Not at all.

Mr. HOSMER. You have a nice statement here on the desalting, but we have a specific bill before us. It wants to spend \$200 million over roughly a 5-year period, at the apparent discretion of the Office of Saline Water.

My first question, Dr. Hornig, is, what relation does the figure \$200 million have to any program of a definite nature? In other words, how is the \$200 million arrived at?

Mr. HORNIG. The Secretary of the Interior and the Atomic Energy Commission presented a report which outlined a projected program in the next 5 years, I believe it is, which is the basis for that estimate.

Mr. HOSMER. Are you talking about this brochure of September 22, 1964, coincidental with commencement of the last political campaign for the Presidency? Is that the document that you are referring to that the Interior supports this \$200 million with?

Dr. HORNIG. That is right. I don't think it should be referred to as campaign literature, though.

Mr. HOSMER. I referred to it as a brochure. I might have added, "a 36-page slick paper brochure."

Dr. HORNIG. I am not sure what the question is.

Mr. HOSMER. Is that what you say supports this \$200 million figure?

Dr. HORNIG. That is the general outline upon which the \$200 million figure is based, yes.

Mr. HOSMER. Then you said that the Atomic Energy Commission submitted something in support of this figure. What brochure are you referring to there?

Dr. HORNIG. The same one.

Mr. HOSMER. Is this all the same brochure?

Dr. HORNIG. That is right. There is a report from the Secretary of the Interior and the Atomic Energy Commission.

Mr. HOSMER. So far as I can see, any definite cost figures are found on page 1 which are the expenditures to date. I am talking about the \$200 million that Mr. Udall wants Mr. Di Luzio and his successor, if any, during the 5-year period, to spend. Over on page 7 we have an allocation between research, distillation, and so forth, but no line items, no reason why \$200 million is better than \$100 million or \$600 million. What is the magic in \$200 million?

Dr. HORNIG. Based on this program, this was the estimated expenditure to produce large-scale plants at the end of that period.

Mr. HOSMER. They are not to produce any large-scale plants under this program. This is limited to research, it is limited to prototypes, pilot plants, it is limited to economic studies, it is limited to cost studies plus making recommendations as to authorizations for the building of such things as demonstration plants, later.

Dr. HORNIG. That is correct, but I think you would agree that there would be no point in undertaking research and development and programs unless one anticipated doing something with the results of that eventually.

Mr. HOSMER. Do you mean you disagree with the research and file theory that is now going on in the Department of Defense insofar as this subject is concerned? It used to be research and development. Now it is research and file.

Dr. HORNIG. I think that any development program undertaken should be with a view to utilizing the results of the program.

Mr. HOSMER. That is fine, Dr. Hornig, but that is another matter. What we are talking about is \$200 million for the specific purposes that I just mentioned, which is to be spent by the Office of Saline water.

What definite relationship does \$200 million over the next 5 years bear to what is a sensible program to carry out those four things?

Dr. HORNIG. It is the best estimate of the magnitude of expenditure which will—

Mr. HOSMER. Based on what? Have you any figures you can give? Do you have any figures which say So much this year for this; so much next year for that and so forth, so it all adds up to a neat \$200 million?

I am not talking about page 7 with the round balloons, there, that are segmented into general categories. "Research, 30 percent." What does that mean?

Dr. HORNIG. I think I will have to refer you to Mr. Di Luzio on the detailed year-by-year projections or otherwise I will have to go back and look into it further myself.

Mr. HOSMER. I would certainly feel that I was being disrespectful and disregarding my oath of office unless I knew what the components of this \$200 million figure were.

Now, let's get into the other factor: Why do you have to have this amount of money now, for 5 years, and stay away from us for 5 years? Why don't you feel it proper that you can come back here like some of the other agencies do and justify your expenditures year-by-year, and get your annual authorization?

Dr. HORNIG. There is still, of course, an annual appropriation required.

I think that the best answer would be that in laying out a research and development program, one needs to look forward to get continuity and get the most effective program.

Mr. HOSMER. What is the magic of the 5-year forward look? Why isn't a 2-year forward look justifiable for the purpose—or 10 years, for that matter?

Dr. HORNIG. In my own view—I can't speak for everyone who is connected with that period—something like a 10-year period might possibly be still better, but that seemed to be the period at the end of which one could look forward to practical results from the program.

Mr. HOSMER. And also probably the most you figured you could get away with; is that right?

Dr. HORNIG. No comment.

Mr. HOSMER. You don't have to answer that.

Well, you know, Dr. Hornig, I was going to ask you more detailed questions—well, I will experiment with one, anyway:

You talk about this \$200 million somewhere involving intensive research on new materials. I suppose materials research is being conducted by at least a half-dozen or more other Government agencies. What materials research do you have in mind?

Dr. HORNIG. There is the problem of the kinds of metals that you can use. Let me say in the first place, I am not really competent to outline in detail all of the researches that would be carried out by all of the people concerned with the program, but there are materials problems in finding metals and heat transfer surfaces which will minimize corrosion.

Materials problems are being studied in many, many industrial laboratories and they duplicate even within themselves, because the materials have to be considered in the light of the projected use of the materials.

Mr. HOSMER. Is that to be construed as a statement in favor of duplication?

Dr. HORNIG. Oh, not at all.

The word "materials" is simply too general.

Mr. HOSMER. That is the trouble. We get these general words up here and we don't go home with anything too specific.

You have all these semantics in here about pilot plants, modules, demonstration plants and prototypes. You understand that only pilot plants and modules are involved in this \$200 million?

Dr. HORNIG. I understand that. I simply wanted to indicate again that the program, nevertheless, must look forward to a prototype at a fairly early date, and this, of course, will need to be separately authorized.

Mr. HOSMER. Dr. Hornig, your statement, particularly with emphasis on the brackish water problem, like so many other statements, does not discuss the problem of disposal of the mineralized effluents from areas that are closed cycle areas.

Dr. HORNIG. I think I mentioned that quite explicitly. The desirability of reusing water.

Mr. HOSMER. I am talking about, like some people say, "It would be a great thing to go out to the Salt Lake and desalt it and use the water," but what are you going to do with the effluent? The reason you have the Salt Lake is that it is a closed cycle area, you have had all your evaporation out of there, and you have had continuous concentration of salt. Whether you accomplish it by evaporation by sunshine or a desalting, brackish-water plant, you have a real problem on your hands in possibly confounding the situation rather than improving it.

That is something I don't think you covered in detail.

Dr. HORNIG. No, and this is a problem which must be solved, as you indicate, in each specific area. It is a very serious problem. You are quite correct.

Mr. HOSMER. What do you propose to do about it for \$200 million?

Dr. HORNIG. I am afraid I will have to defer to Dr. Di Luzio on that question.

Mr. HOSMER. Let's evaluate Mr. Di Luzio's proceedings, here. And this is my last question: Mr. Di Luzio has gone out and let 15 different contracts for a study of a large desalting plant. Apparently on a kind of a Monte Carlo basis, hoping that the laws of average will give maybe some information he hasn't got.

Is that really an accepted scientific approach?

Dr. HORNIG. At the first stage, before narrowing it down, I think this is a very reasonable approach. When one looks at this problem there are very many detailed engineering approaches, very many kinds of heat cycles that one can put together and they have been looking for economy—and this is what it means in the conceptual studies. One looks for some optimum combination of ways of doing those things. The problem is how to make this the most efficient plant. One starts with very small studies, and from thereon, one begins to home in on the target.

Mr. HOSMER. You couldn't get just as much by going to one company and asking them to come up with 15 different concepts, or 5 companies, and asking them to come up with 3? I am trying to get to the magic in the number 15.

Dr. HORNIG. I don't think there is any magic in the number 15. I am afraid I don't remember just how the number 15 was determined. I had thought the first round was essentially open to those people who wanted to participate, with quite reasonable proposals to make.

Mr. HOSMER. I know we have more witnesses this morning. I am sorry we can't get into the matter also of evaluating Commissioner Ramey's contention that we have to spend many millions of dollars developing a certain type reactor to give a certain temperature of

steam to support the few giant plants that could be located in the entire geography of the world for desalting purposes, but I am not going to get into that.

Dr. HORNIG. The desalting plant, itself, doesn't know from where it got its heat, a gas-fired plant or an oil-fired plant, or what it is. It only receives heat which has some cost. Beyond that the question which is related to Mr. Ramey's testimony is, How does one in a given locality produce heat for the desalting part at the lowest possible cost.

Mr. HOSMER. And it involves questions of economics in many areas. Water economics, power economics, geographic economics. My contention being, Dr. Hornig, that nobody has taken an inventory of how many areas there are where this kind of giant operation could feasibly be introduced into the local economy, and therefore I think it is premature that we spend all this money trying to develop something which may have such a limited use.

Thank you.

Mr. ROGERS. The Chair would remind the other members that we do have a great number of witnesses, many from out of town, and we can't meet past 4 o'clock this afternoon. If you would cooperate, it would be appreciated.

Mr. HALEY.

Mr. HALEY. Dr. Hornig, do you have any figures to present to us as to the amount of water used or consumed by the people of the United States, per day?

Dr. HORNIG. I am afraid I can't tell you, offhand.

Mr. HALEY. Doctor, you are an expert on this. As an adviser to the President of the United States, it would seem that you or your office should have something that would indicate the consumption of water per day. Maybe we have got too much water. I realize it is not held in the proper place sometimes, but it seems to me that would be one of the basic facts to find out, here: How much water is consumed in the United States each day and each year.

Dr. HORNIG. It is something I am sure I can produce for you very shortly, but I can't produce it from the top of my head.

Mr. HALEY. Produce it for the record, then.

Mr. ROGERS. Without objection it will be included in the record. (The information requested follows on p. 172.)

Mr. HALEY. What percentage of the water—do you have any figures on this—what percentage of water could be produced in a project of this kind?

Dr. HORNIG. A very small percentage of the total water, because a very large part of the total water consumed in American is for agricultural purposes, and this would have very little relation to that. It would even be a very small part of the municipal and industrial water.

Mr. HALEY. I realize that within certain localities water is critical, but is any consideration given here to developing some method of storage of natural waters? It seems to me like, with \$200 million, we could build a big pipeline from here to the gentleman's dry, arid place out in California and divert possibly the Mississippi River out there. That would solve the problem out there, wouldn't it?

Dr. HORNIG. Not for \$200 million.

Mr. HALEY. You have asked for \$200 million and I am afraid that is just a little start.

At page 3, Doctor, you state this: It begins on line 3, page 3. "We need to know more about corrosion of the many materials available for use and more about the physical chemistry of salt solutions. We must improve the rate of heat transfer within the processes."

Do you have to do these things on a large scale? Couldn't you find that out by a simple little pilot plant that is operated for a while?

Dr. HORNIG. Most of the things I speak about are laboratory experiments or pilot plants.

Mr. HALEY. Doctor, with your present progress in this project you are nowhere near producing this potable water, from either brackish or salt water, or anything else, that would put it even within reasonable use for agriculture?

Dr. HORNIG. I am not aware of any plant we could build now or in the very near future that would come close to being suitable for irrigation water.

Mr. HALEY. I think that is all.

Mr. ROGERS. Mr. Wyatt.

Mr. WYATT. Would you outline briefly to us the other areas where water research work in desalination is presently being conducted?

Dr. HORNIG. There is, of course, work on ground waters, the hydrology of ground waters.

There is research on streams and lakes, pond evaporation and transpiration of water, storage. There is a great deal of work now going on, on water pollution and the abatement of pollution. There is work going on, on many aspects related to flood control and the storage and reclamation of water. The survey of ground water resources and quality control in our streams—I don't know what detail you want.

Mr. WYATT. What other areas of water source to this country, where research is being conducted, are there?

Dr. HORNIG. I think the big things are ground water, streams, lakes, underground supplies and all other things connected with it, research related then to the utilization of water from conventional sources.

Mr. WYATT. How about the reuse of waters?

Dr. HORNIG. The reuse of waters and this is also related in terms of water pollution and abatement of pollution. All these problems overlap, some.

Again, it is related to the treatment of waste water from cities, such as sewage disposal.

Mr. WYATT. Can you state as the President's Science Adviser, the order of priority of these various programs relative to their greatest potential toward solving our water problems, both present and future?

Dr. HORNIG. There are many different water problems which we need to solve. We have water problems in the eastern part of the country where we are heavily industrialized, which aren't related to desalting at all, but which are really related to the problems of reuse, purification and pollution. The problems in the Southwest or in California are entirely different. They are largely questions of the total availability of water. It is not quite right to just look at the total. One has to look at the various water problems we have to solve and say, "Are we doing the right things to solve them?"

Mr. WYATT. Are any of the other water research programs that you have referred to being increased, or is there a request in, has there been a request in to increase any of the water research programs by anything like the request here to increase the desalinization program?

Dr. HORNIG. Not to my knowledge, in this year's budget.

I would like to tell you briefly what we are doing. Last year for the first time—that is the book I held up—we attempted to collect in one place the totality of the work that was going on in water research which covers many areas.

This year we are trying to go a step further, now, and to really assess the totality.

Mr. HALEY. Doctor, do you have any idea of the amount of research and the amount of money being expended now by private enterprise, going toward reuse of water, to purify it and make it potable, after use?

Dr. HORNIG. No; I can't give you the answer to that. I don't know whether that number is available. I can attempt to find out.

Mr. HALEY. We are spending a lot of the taxpayer's money. Many of these manufacturing plants, and so forth, are spending a great deal of money. In my own State of Florida where we have huge phosphate mining interests the people down there, the phosphate operators are using huge sums of money to remove the impurities from water. Is there no place that that information is being gathered so that we would not have a duplication of spending taxpayers' money and private enterprise spending their own money to try to solve these things? Are you working in cooperation?

Dr. HORNIG. Yes; we are trying to collect it in one place, now, particularly in the Science Information Exchange of the Smithsonian Institution. It has been assigned the responsibility of collecting all of the available results of water resources research, so they are available to everyone.

Mr. HALEY. Thank you.

Mr. WYATT. One more question and I will be through, Mr. Chairman.

Doctor, can you give us any reason why the area of desalinization has been picked for this big geometric increase in appropriations, rather than any of the other water research areas that could serve as a source of solving this country's water problem in the present and the future?

Dr. HORNIG. Basically because the time is right. We have been working in many areas for a long time, but in many parts of the country we need all the sources of water we can get and the OST study, which is a fairly hardheaded one, showed that the time was now right that one could project the addition of a new economic water source. So we proposed to go forward.

Mr. WYATT. That applies to the desalinization program rather than any other water research program that was singled out for the most dramatic increase in effort?

Mr. HORNIG. Yes. You see, it was only a few years ago it began to be realized that by going to large enough scale, one could clearly become economic.

Some of the industrial people will tell you we need not go to the large scale originally envisioned and still can make it economic, that would make the situation even better than we thought.

Mr. ROGERS. Mr. Tunney.

Mr. TUNNEY. Have there been any specific cities to come forward who could afford to build plants and distill water from those plants?

Dr. HORNIG. This depends upon what scale one has to go to get the cost down. I am not aware of a detailed study, city by city. In the

OST report I think Southern California is shown as the most promising area. As the scale comes down, there come to be more and more and more areas that are water-short areas where desalting could be applied.

Mr. TUNNEY. Do you know whether or not there have been any figures given or any specific cities or communities singled out as areas that could build a plant in 1972 or 1973 or 1975, using these techniques?

Dr. HORNIG. Several have been mentioned, but this is the main point of the economic studies in this year's budget—to go ahead and look in detail at a series of sites.

Mr. TUNNEY. You heard, today, there is a problem in coordinating water development programs at the developmental research level before there were actually any findings. Is this true, and if so, is it being corrected?

Dr. HORNIG. I don't know if the word should be "corrected." It is my responsibility under Reorganization Plan No. 2 of 1962, to coordinate research and development programs. It is quite correct there is work on pollution control and water reuse by the Department of Health, Education, and Welfare, which can be extended to this program, and there is work on water purification, the benefits of which can be extended to HEW. This is why I maintain an interagency Committee on Water Resources, which is the source of this volume, to coordinate this work and, as I say, it is my responsibility to see that it is effectively coordinated.

Mr. TUNNEY. We cannot cast any aspersions on the good work you are doing, but we did hear today, although there was a dissemination of the findings of the various programs, at the development stage, while the research was actually being done, there was not good coordination in the past. I was just wondering if you were aware of this?

Dr. HORNIG. I will look into it even harder.

Mr. TUNNEY. Thank you. I have nothing further.

Mr. ROGERS. Mr. Reinecke.

Mr. REINECKE. Did you advise favorably to the President on this program?

Dr. HORNIG. I certainly concur in this program.

Mr. REINECKE. The reason I am concerned, we are asking for an authorization of some \$200 million but I feel a lack of specific knowledge of the particular program. It seems we are asking for a lot of money without really knowing what we are spending it on.

Dr. HORNIG. I presume the annual program will be reviewed in detail during the appropriations meetings each year.

Mr. REINECKE. Is your job primarily administrative or are you going to be involved in the technical aspects of the field as well?

Dr. HORNIG. Not in the detailed part.

Mr. REINECKE. Do you have a setup in your office to evaluate these research programs?

Dr. HORNIG. I have a very able fulltime man, one, who heads up our work on water resources. He works together with an interagency committee in which all of the agencies participating in water resources work participate. We have a committee, of the President's Science Advisory Committee, which is completely drawn from outside the Government to help us evaluate these programs, and we call in

expert consultants as necessary, if we become concerned about technical areas in the program.

Mr. REINECKE. It was their advice, after evaluating previous R. & D. programs that we should go ahead at that rate, is that correct?

Dr. HORNIG. I don't think this detailed budget has been submitted to any of our outside advisory programs.

Mr. REINECKE. In your statement on page 5 you say it is not yet clear whether industry can, in the immediate future, adapt the technology to the design of plants producing water.

Why are we spending \$200 million if this is not clear?

Dr. HORNIG. The word "current" is the key one. It has been sometimes argued no development is necessary because in terms of what we know right now, industry could produce competitive plants; in some areas of high-cost water that is certainly true now, but we are spending the money precisely so that industry, we hope, will be able to produce lower cost water in the future.

Mr. REINECKE. From your statement here it sounds like we need major breakthroughs, but we should not be in the prototype or hardware stage yet, until we have something upon which to proceed.

Dr. HORNIG. I think if there were no advances in technology whatever, we could now make plants which were competitive for some purposes in some areas. With technological advances the cost ought to come down. What one wants to do is to learn how to reduce the capital cost of plants by having simpler cycles, which have cheaper materials, and this is what the research and development work eventually aims at.

Mr. REINECKE. I think it has been indicated by other members, here, we are spending an awful lot on something that perhaps doesn't justify the priority position set out.

You mentioned in answering Mr. Aspinall a few minutes ago that you don't know a better way to spend the money. Is the objective of your office just to spend money?

Dr. HORNIG. No. The office has many objectives, but one is to see that the country gets the most from the best applications of science and technology.

Mr. REINECKE. I have the feeling from the statement which you made that you have a quota to spend so many hundreds of millions of dollars a year on research, and you are going to spend it one way or another.

Dr. HORNIG. Not in the least. I have been charged upon occasion with operating an office for the prevention of science and technology, as well as being charged with wanting to spend too much.

Mr. REINECKE. Thank you.

No further questions, Mr. Chairman.

Mr. ASPINALL. Thank you very much, Dr. Hornig.

(Supplemental information submitted by Dr. Hornig follows:)

MAY 27, 1965.

Hon. WAYNE N. ASPINALL,
House of Representatives,
Washington, D.C.

Dear CONGRESSMAN ASPINALL: In order to clarify my responses to some of the questions raised by your committee during my testimony on May 20, I would like to submit further data.

I enclose copies of two reports describing the water resources research programs of the Federal Government for fiscal years 1965 and 1966. The reports follow

the tabular format developed in the Report to the President on Water Resources Research prepared by the Federal Council on Science and Technology and published as a committee print of the Senate Committee on Interior and Insular Affairs in March 1963.

The Federal Council Committee on Water Resources Research has been at work during the past several months developing a basis for a planned program of water resources research. In the course of their work they found the tabular breakdown which has been used previously to be rather unsatisfactory for relating the research program to the Nation's needs. They have devised a new system of categories which is more meaningful and I am attaching as an appendix to this statement a breakdown of the research for fiscal year 1965 and the budget for fiscal year 1966 on this new system.

The desalting research program of OSW is distributed among these categories as follows:

Desalting research program

[In thousands of dollars]

	Fiscal year 1965	Fiscal year 1966
I. Nature of water:		
(a) Properties of water	1,200	1,300
(b) Aqueous solutions	1,400	1,550
III. Water supply augmentation and conservation:		
(a) Saline water conversion	4,950	22,650
(c) Use of water of impaired quality	625	1,025
V. Water quality management and protection:		
(d) Waste treatment processes	170	450
(e) Ultimate disposal of wastes	350	575
(f) Water treatment	955	1,100
IX. Manpower, grants, and facilities: (c) Research facilities	350	350
Total	10,000	29,000

Thus the desalting effort represents about 15 percent of the 1965 Federal water resources research program and 28 percent of the 1966 program.

There are a number of factors which contribute to these percentages. The report of the Kerr committee disclosed that water shortages were impending in the not too distant future. An answer to water shortages in some areas clearly lay in desalting. Research on desalting had been underway for several years and had progressed to the point where some significant advances appeared possible. Because of the experience already accumulated we were ready to put a program together. It seemed clearly wiser to advance a front where we were prepared to advance than to hold back on all fronts until a uniform advance was possible across the board.

There are, indeed, other areas of need in the water research field. Since early this year the Committee on Water Resources Research of FCST, supported by an OST Panel on Water Resources Research, has been reviewing the research needs in all aspects of water resources. This review is progressing and will be ready in time for budget planning for fiscal year 1967. It will identify the principal areas of need and opportunity, state where research can and should be profitably extended, and evaluate the present programs. Because their appraisal is incomplete it would be premature to attempt to outline these needs in detail here. It is clear, however, that the area of waste treatment and waste water reclamation is one area of special need. Another area of importance is water quality control by methods other than waste treatment. Research on the methods of planning and evaluating water resource systems will undoubtedly also be highlighted as will a number of other areas.

In 1964 the President asked Interior and AEC to prepare a forward-looking program of desalting research. Their report proposed a program of \$200 million through fiscal year 1972. Like any research plan, the proposal reflects the judgment of experienced men as to the magnitude of effort required but as in all research and development programs, the year by year needs cannot be pinpointed in advance.

There is a level of effort which will move a program ahead at the most efficient pace. To substantially exceed this level requires programing efforts in such a way that a particular area of investigation may be attacked before the underlying and supporting effort is fully developed.

Programing at a level below the optimum, inevitably delays the completion of the work. It may also increase cost because some elements of effort are retarded by delays in related elements. The requested \$200 million represents our best estimate of the optimum level of effort.

A desalting research program requires several years. Laboratory research, construction of pilot plants followed by modular units and prototypes cannot be done in a single year. Consequently if there is to be efficient planning there must be some agreement on the funds to be available over a period of years. The proposed program has for its goal completion of a major prototype by about 1970. Conclusions regarding future program cannot be firmed up before that prototype is in operation and some results have been obtained. Allowing for the time delay in the budget process, authorization extending through fiscal year 1972 is necessary as a minimum to permit effective planning of current program, evaluation of results, and preparation of proposals for the Congress concerning further work.

In reply to Mr. Haley's question concerning current water use in the United States, we are now withdrawing about 300 billion gallons daily from our surface and ground-water resources. This includes industrial, municipal, and agricultural uses. This does not include recreation and hydropower uses which are not diverted from our streams. About one-third of this diversion or 100 billion gallons daily is actually consumed. The remainder is returned to the streams and ground water somewhat less pure than when diverted.

Sincerely,

DONALD F. HORNIG.

Federal water resources research program

[In thousands of dollars]

	1965 estimate	1966 budget
I. Nature of water:		
(a) Chemical and physical properties of water	1,200	1,300
(b) Aqueous solutions and suspensions	1,520	1,670
Subtotal	(2,720)	(2,970)
II. Water cycle:		
(a) General	2,166	2,433
(b) Precipitation	490	511
(c) Snow, ice, and frost	310	355
(d) Evaporation and transpiration	799	931
(e) Streamflow	1,726	1,888
(f) Ground water	1,438	1,496
(g) Water in soils	974	970
(h) Lakes	100	100
(i) Water and plants	735	698
(j) Erosion and sedimentation	2,104	2,119
(k) Chemical processes	1,017	1,230
(l) Estuarine problems	470	490
(m) Ecologic impact of water development	1,575	1,675
Subtotal	(13,944)	(14,896)
III. Water supply augmentation and conservation:		
(a) Saline water conversion	4,950	22,650
(b) Water yield improvement	2,215	2,022
(c) Use of water of impaired quality	712	717
(d) Conservation in domestic use	0	0
(e) Conservation in industry	0	0
(f) Conservation in agriculture	981	960
Subtotal	(8,858)	(26,349)
IV. Water quantity management and control:		
(a) Control of water on the land	1,889	2,005
(b) Groundwater management	318	397
(c) Effects of man's related activities on water	515	554
(d) Watershed protection	1,200	1,213
Subtotal	(3,922)	(4,119)

Federal water resources research program—Continued

[In thousands of dollars]

	1965 estimate	1966 budget
V. Water quality management and protection:		
(a) Identification of pollutants.....	1,278	1,297
(b) Sources of pollution.....	700	1,311
(c) Effects of pollution.....	4,000	5,009
(d) Waste treatment processes.....	1,665	3,170
(e) Ultimate disposal of wastes.....	1,432	1,593
(f) Water treatment.....	1,365	1,280
(g) Water quality control.....	779	1,442
Subtotal.....	(11,219)	(15,102)
VI. Water resources planning:		
(a) Techniques of planning.....	155	213
(b) Evaluation process.....	163	331
(c) Cost allocation, cost sharing, pricing, and repayment.....		
(d) Water demand.....	401	490
(e) Water law.....	46	70
(f) Nonstructural alternatives.....	83	93
Subtotal.....	(848)	(1,197)
VII. Resource data:		
(a) Network design.....	180	180
(b) Data acquisition.....	1,151	1,136
(c) Evaluation, processing and publication.....	560	560
Subtotal.....	(1,391)	(1,876)
VIII. Engineering works:		
(a) Design.....	1,728	1,944
(b) Materials.....	760	795
(c) Construction and operation.....	1,855	2,043
Subtotal.....	(4,343)	(4,782)
IX. Manpower, grants, and facilities:		
(a) Training and fellowship grants to universities.....	2,617	3,210
(b) Government Employees Training Act.....	1,181	1,376
(c) Research facilities.....	850	4,400
(d) Grants, contracts, and research act allotments.....	23,155	21,037
Subtotal.....	(27,803)	(30,023)
Total.....	75,048	101,314

Mr. ASPINALL. The next witness will be Dr. Rolf Eliassen, professor of sanitary engineering, Stanford University.

As we start with these remaining witnesses the Chair wishes to express appreciation for the fact that most of the remaining witnesses are those who responded to the invitation of the Chairman to be present at the hearings today.

STATEMENT OF DR. ROLF ELIASSEN, PROFESSOR OF SANITARY ENGINEERING, STANFORD UNIVERSITY

Dr. ELIASSEN. Thank you, Mr. Chairman. I appreciate being invited to attend.

I am chairman of the American Water Works Association on the Saline Water Conversion Committee. They have asked me to express their ideas on some of this, too. We have about 19,000 members. We represent all the waterworks in the country and outside the country. We have a good number of members there, too.

In general we are in favor of this increased appropriation in your bill and we know we will get cheaper costs from this experimental work, this demonstration work, because I am a laboratory man essentially but also a consulting engineer—the larger we make these things the lower the price can become because we can do it on a large scale but we don't know many things about this.

I think many people will testify about the distillation, nuclear reactors, and things. I am convinced you can bring the price of water down to 25 to 30 cents a thousand gallons by this work and we have to prove reliability of operation and economy, and also we want to be shown. In order to be shown we have to have a lot of these plants, or some of them, built so we can see what has happened.

This program will benefit many of the large water utilities in the coastal areas.

Reverse osmosis has a big piece of that pie and that has a real future.

It will take a good number of years to research that, develop it, and make it practical. We certainly encourage the Office of Saline Water to expand that program.

There are two other things I want to mention particularly from the standpoint of myself and the American Water Works Association from the State I represent. In California we have so many water supplies, for instance, which are above the limit that the Public Health Service recommends, 500 parts per million total. There are over 1,000 communities in the United States that have over 1,000, twice as much salt, in the water as the Public Health Service recommends. This is true not only of California but Texas, Kansas, all along the whole eastern seaboard.

The gentleman from Florida has many problems, but all the way from the Dakotas down to Texas and New Mexico there are large areas and huge reserves of brackish brown water which these communities can take care of.

In the southern part of California we can afford to import water from the north because we transport huge quantities, but the small communities cannot afford to transport water very great distances because not many people use this water, so we would like to see much more work done on the brackish waters which are underlying so much of this country.

You have it in Colorado, around Durango, and we have it in many other States.

The report that Mr. Hosmer mentioned the recharge of ground water for desalinization, to try to keep the ocean out, this is a problem in Hawaii and this is a problem in many other places, particularly from Massachusetts down the entire eastern seaboard to Texas and the west coast of California. We have Orange, Ventura County, and Los Angeles Counties which have real problems. The sea water comes inland at the rate of a thousand feet a year because they are pumping so hard out of this.

One good method of keeping sea water out is to put some fresh water into the whole aquifer. We haven't a lot of fresh water to put in. In answer to somebody's question here, there are about 200 million acre-feet a year of waste waters, once-used waters. It is a crime to use it once and throw it out. Sea water is about 96.5 percent solids and

3½ percent impurities. Sewage of these waste waters is 0.9 percent pure water, only 0.1 percent being foreign matter. We can purify these.

The Department of Health, Education, and Welfare is doing some of this work, and this is part of the whole water research budget.

One thing about once-used water is that as the people use it they add salt to the water from the human body. You have a lot of sodium chloride which goes into the water, so you should demineralize this before you put it back into the ground.

In counties like Riverside, Orange, and San Diego Counties we can do that if we can demineralize some of this and freshen up the water.

You can take out some of the salt. It is the salt that is difficult to take out.

The plants we have built so far, electrodialysis, they are all small. Membranes are made practically by hand. If we had larger plants, there are three manufacturers, we could get them to reduce costs by this method, but there is not the market.

As Dr. Hornig brought out, the market is the important thing. This market can be created, and the market is greater the cheaper this kind of process becomes.

Therefore I would make a plea that you and your committee consider adding something, or consider using some of this money.

I am sure Mr. Di Luzio has this in mind, to have a program for brackish water for the inland water supplies.

One of the big problems in brackish water is what do we do with the salt we take out of the water? We haven't all the answers yet. We have a lot of work to do on this thing.

Tucson has a project now they are starting and trying to work out here. However, you have to put the water back into the ground but take out some of the salt before you put it back into the ground.

This is true in many other places.

Therefore let me stress this: From the standpoint of the American Water Works Association, from my own standpoint as a research man, and as a member of some of the committees that get into this type of work, we are interested in this. If you have 200 million acre-feet of water a year, once-used water, is there not a possibility we can recover only 20 percent of this water or even 10 or 12 percent? Then we could get 25 million acre-feet of water, or maybe more. Therefore it is worth spending \$25 million to look at the demineralization and desalination of these waste waters and brackish ground waters to increase the potential water supplies for many of these communities.

In summary, then, we encourage the passage of H.R. 7092, in addition to the extensive program which these pies show for reverse osmosis and distillation I would recommend mature consideration be given to the desalting of inland brackish water supplies and municipal waste waters.

Great economies over present costs can be achieved by such programs.

Mr. ROGERS. Thank you, Doctor.

Without objection your written statement will be included in the record as if it had been read in.

(Dr. Eliassen's statement follows:)

STATEMENT OF DR. ROLF ELIASSEN

My name is Rolf Eliassen. I am professor of sanitary engineering at Stanford University and a partner in the firm of Metcalf & Eddy, Engineers, of Palo Alto, Calif. I have been associated with the water resources profession for the past 30 years, specializing in water supply, treatment, and distribution. During most of that time, I have been a member of the American Water Works Association and for the past 5 years have been chairman of its committee on saline water conversion.

The American Water Works Association has designated me to represent its 19,000 members before your committee. The possibility of expanding, extending, and accelerating the program of the Office of Saline Water under the Secretary of the Interior, through the implementation of H.R. 7092, is of great interest to the American Water Works Association. We believe that such an expanded program could lead toward a significant reduction in costs and increase in reliability of operation for saline water conversion plants, not only those obtaining fresh water from the sea, but for the greater number of plants which will tap the vast underground reservoirs of brackish waters in the inland areas of this Nation. We recommend approval of H.R. 7092.

The large-scale distillation plants proposed in Secretary Udall's report to the President on a program for advanced desalting technology should go far in achieving lowered costs of fresh water from the sea, particularly when these plants are combined with nuclear reactors for electric power generation. I believe that the cost of fresh water at the seacoast can be brought down to the range of 25 to 35 cents per 1,000 gallons in plants with capacities of 100 million gallons per day. Economy is possible by building large plants. Reliability of operation and economy of production can be proven to the waterworks profession by the large operating units provided for under H.R. 7092. This will benefit the large water utilities in the coastal areas of the United States, as well as many other water-short areas in the world.

I believe that reverse osmosis has real potentials for the economical production of fresh water from the sea and brackish waters. Based on experience with other desalting processes, it may take 5 to 10 years of research, development, and demonstration to make this process practical for waterworks use. The Office of Saline Water should be encouraged to expand their work on reverse osmosis manyfold.

There are two other aspects of desalting which the members of the American Water Works Association would like to bring to the attention of your committee. The first is brackish water desalinization for the more than 1,000 inland communities—from the Middle West to the Dakotas to Texas and Arizona. If the brackish waters which they now use could be desalted more economically, there would be a great improvement of public water supplies over a large area of the country.

Our studies have shown that the electrodialysis process or vapor compression distillation may be the keys to better water supplies from brackish wells. Vapor compression distillation has reached a high degree of development through extensive use in many areas. The Office of Saline Water is carrying out extensive work in the demonstration plant at Roswell, N. Mex., using vapor compression units.

It is suggested that funds be allocated to build a large electrodialysis plant, perhaps up to 10 million gallons per day. Economies to be achieved in large-sized distillation units also may be expected with the electrodialysis process. Cheaper membranes, better hardware and more economical use of power could be expected from a \$20 million program directed toward the solution of problems of inland cities which must use available sources of brackish ground water.

We urge you to consider another field of research and development which offers a great potential for the economical recovery of water. I refer to the reclamation of waste waters and the recharging of these into the ground, particularly in the areas mentioned in the report to the President as "islands and coastal areas where the mining of ground water supplies has resulted in sea water intrusion." This intrusion has been caused by heavy pumping in coastal metropolitan areas and has ruined many water supplies along the Atlantic, gulf and Pacific coasts—from New England through Florida and Texas to California. Three large counties of southern California, Ventura, Los Angeles,

and Orange, are faced with this problem and are considering the injection of reclaimed waste waters to build up underground hydraulic barriers against the sea. Municipal waste waters amount to almost 200 million acre-feet per year. If 20 percent of this great volume of flow could be recovered, it would constitute a genuine breakthrough in developing vast quantities of reusable water.

At Stanford University, we have a pilot plant study, financed by the demonstration grant program of the Division of Water Supply and Pollution Control of the U.S. Public Health Service, on the reclamation of Palo Alto sewage. We are able to take out most of the objectionable materials and put this water into the ground at \$15 to \$60 per acre-foot. This is being proven on a large scale by the Los Angeles County Sanitation Districts. However, the activity of humans adds from 200 to 400 parts per million of salts to the water. Before discharge of the purified wastes into the ground in hard water areas, desalting should be practiced in order to prevent a buildup of salts in the ground waters and thus make them less desirable for use. Electrodialysis is the key to this desalting operation. Reverse osmosis may be applicable eventually, but this process is not as effective in the removal of the common salt, sodium chloride, as electrodialysis.

The American Water Works Association is intensely interested in having your committee provide adequate funding for the Departments of the Interior and Health, Education, and Welfare for research, development, and demonstration work in the desalting of reclaimed waters before discharge into the ground. It is believed that this can be an economical source of new waters and one of the real hopes for combating the impending water shortages in many areas of the country. This includes inland areas where ground waters are being used at a higher rate than they are being replenished by rainfall. States such as Illinois, New Mexico, Texas, and Arizona are among many faced with depletion of ground water resources. An extensive study could be conducted by the Office of Saline Water, in cooperation with other State and Federal agencies, on the need for and means of achieving reclamation of waste waters through purification and desalting. This program would be worth an investment of \$25 million, which is a small price to pay for the potential recovery of over 25 million acre-feet per year of water.

In summary, we encourage the passage of H.R. 7092 and, in addition to the extensive program envisioned for distillation and reverse osmosis, we recommend the appropriation of substantial sums for work on the desalting of inland brackish water supplies and municipal waste waters. Great economies over present costs can be achieved by such programs.

Mr. ASPINALL. Doctor, do you or any of your associates have any contractual agreements with the Office of Saline Water?

Dr. ELIASSEN. Yes, sir, I have one now, our firm of consulting engineers, studying the economies of water in California. There are so many problems here. How much does water cost?

Mr. ASPINALL. We cannot go into that. I just wanted the answer to that question.

Dr. ELIASSEN. All right, sir.

Mr. ASPINALL. You were a member of the committee which prepared the report to the President, program for advancing desalting technology?

Dr. ELIASSEN. Yes, sir.

Mr. ASPINALL. Did you in your report have anything to say about the amount of money necessary for the proposed future plans in this area?

Dr. ELIASSEN. No, sir. Our objective was programs.

Mr. ASPINALL. Thank you, Mr. Chairman.

Mr. HOSMER. In your written statement you speak of the advisability of the constructing large operating units provided under H.R. 7092. What do you refer to there?

Dr. ELIASSEN. In the case of electrodialysis, for instance, I was thinking of 10 million gallons a day, where we can get—

Mr. HOSMER. Talking about a demonstration plant of some kind?

Dr. ELIASSEN. Yes, sir; this is a demonstration plant.

Mr. HOSMER. Under the authority of the law the Office of Saline Water cannot go beyond a pilot plant or a module stage. This \$200 million will not go for any large operating unit. It does not fall in that category.

Dr. ELIASSEN. This would be a module, you can say. There is a lot to be learned. For instance, in Kansas there are many waters that have different properties. You will not find out how to operate this unless you have an operating unit. These waterworks operators have to be shown the problems which cannot be worked out in the laboratory.

Mr. HOSMER. We understand that. I wanted an idea of what you were talking about and what you were referring to.

Dr. ELIASSEN. Yes, sir.

Mr. HOSMER. You have no particular knowledge on whether Congress should make this authorization for 5 years, 3 years, 8 years, or some other arbitrary period of time?

Dr. ELIASSEN. In the research we are doing for other agencies 5 years is the minimum we like to see so that we can plan. It takes so much time to develop research and continue to the development stage until you can come up with some hardware. You have to have enough assurance that you will have a program that will be of sufficient duration to plan for the whole part of it. Otherwise so many programs end in midair.

Mr. HOSMER. You don't mean to say that with a 2-year authorization everything would fall to pieces and collapse and nobody would come back to Congress and get it for another 2 years?

Dr. ELIASSEN. No, sir; but it helps a lot if you can plan for 5 years on a research program and development program because it takes time.

Mr. HOSMER. It is a lot if you don't know where they are spending the money, though.

Dr. ELIASSEN. You have to have some control. I admit that.

Mr. UDALL. I have no questions, Mr. Chairman. I did appreciate the statement of the witness. I was particularly touched by his mention of the city of Tucson, one of the jewels of the Southwest.

Mr. SKUBITZ. I have no questions, Mr. Chairman. I am glad to have had the witness with us today.

However, there are many things I would like to visit with him about regarding Kansas but I don't want to take the committee's time at this time.

Mr. WYATT. I appreciate the doctor's statement. I have no questions.

Mr. REINECKE. Does the AWWA have any programs of research in this field at all at the present time?

Dr. ELIASSEN. We have no money. This is our problem. We are made up of poor waterworks operators from all over the country. We have research committees, Research Committee of Saline Water Conversion which I head, but we haven't the money.

Mr. REINECKE. I didn't mean funding actually. Because you have so many members and water companies all over the country it would seem somewhere along the line you should have some programs even if only academic.

Dr. ELIASSEN. This is true. We have a big research committee with many subcommittees and many of the people on those committees are conducting research through support of Government funds and private funds. There is an active research program.

Mr. REINECKE. You mentioned different waters in the great State of Kansas, for instance. Do you feel it is Federal responsibility to get in and analyze and solve these problems or should the State do this?

Dr. ELIASSEN. I don't think Kansas can solve its own—I think Kansas and California can solve its problems. Consulting engineers, of whom I am a representative, can solve these problems, but this is a national problem and the answers are not here today, economical answers are not here.

I have a map here showing it is all over the United States where we have a problem. We are not particularly concerned with one place.

If it were only one State I would say let them solve it. However, if it is a national problem, why aren't people desalting waters now? It is too expensive. The hope is cheaper processes. That means better water for more people.

Mr. ASPINALL. Doctor, you got in one new thought here which has not yet been proposed, and that is in favor of a module or component of considerable size on the electrodialysis process. I think the best operation we have had so far, so far as I can see from demonstration plant operations, is at Webster, S. Dak. Do you have any material that would give us a feel as to what can be gained by going from a 100,000-gallon-per-day plant to a 250,000-gallon-per-day plant or a large plant in the electrodialysis plant operation? Is this not pretty well fixed so far as units are concerned?

Dr. ELIASSEN. If you see a picture of an electrodialysis plant, there are a lot of small boxes.

Mr. ASPINALL. I know about that. I want to know if you have something we can use as foundation material regarding the necessity for a large component in this particular field or is this just part of your thinking?

Dr. ELIASSEN. It is more than thinking. I have talked with the manufacturers and asked several of them, Why can't you make cheaper membranes? This is the big problem. Cheaper membranes can be made if a market develops for these and they can have more modern processes.

Since Webster was built a number of developments have taken place in membranes. We would like to go from this size box to a much bigger one.

Mr. ASPINALL. I understand that, but Doctor, you will not do this simply with research. You prefaced your remarks regarding the market. Of course, if the market were available private industry would step in immediately and grab this and go ahead with it because they have the fundamentals in this.

Dr. ELIASSEN. Yes, sir.

Mr. ASPINALL. All I wanted to know was whether or not you had some foundation materials to show what could be gained.

I don't care about just additional membranes or additional piping or anything like that but something on which we can base our judgment in making a decision.

Dr. ELIASSEN. All I can say is that on the basis of my experience with a number of sewage treatment plants, water treatment plants, and demonstrating this to the waterworks profession, this has to be done and it can be done with a unit of this type.

Mr. ASPINALL. Do you favor the building of a module sewage plant as a research plant for cities? We have never had it. Our cities have built their own sewage plants and depended upon their own engineers with the help of the Federal and State authorities and they have built them through private enterprise. You do favor building a large component or a module for a sewage plant, do you?

Dr. ELIASSEN. Yes, sir; I do. It is being done. The normal sewage treatment plant as primary and secondary treatment, we know about these things. However, the extra pollution that is coming into the rivers now—for instance, New York City spent \$1 billion and they are no further ahead in the harbor than when they started.

Mr. ASPINALL. You have not yet answered my question. Tell me where there is some Federal installation of a large demonstration plant or module or component for a sewage treating plant.

Dr. ELIASSEN. At Palo Alto, Calif., Stanford University has money from the Public Health Service for a demonstration plant for tertiary treatment to take phosphates and nitrates out of water so that this water will not lead to tremendous destruction of water resources by algae growths.

Mr. ASPINALL. How much money is involved?

Dr. ELIASSEN. We have had about \$250,000 allotted.

Mr. ASPINALL. You haven't anything as large and as expensive as we have at Webster in the saline water program. In other words, there just are not any.

Dr. ELIASSEN. No, sir; but the next stage is to prove this. We are just at the primary stage now.

We have to prove this on a larger scale. This will be done under the demonstration grant program of the Department of Health, Education, and Welfare, I hope and believe. This has to be done, sir.

Mr. ASPINALL. That is all.

Mr. HOSMER. You brought up the matter of a study on economics?

Dr. ELIASSEN. Yes, sir.

Mr. HOSMER. This is a subject that is not very popular with anybody in the business but it comes up once in a while, using a salt water flushing system along coastal areas. What is the alternative to that, vis-a-vis cleaning up the water and reusing it as you suggest?

Dr. ELIASSEN. This would be a duplicate system, such as in Ventura, where you have to have two systems.

Mr. HOSMER. As you have on board ship.

Dr. ELIASSEN. Yes. The cost of a new water distribution system, the tremendous problems of corrosion from salt water, the Navy and Coast Guard have fantastic problems on that, and the Health Department has ruled against the cross-connection between salt and fresh water. This is also part of economics. It would be more expensive to do that for the system as a whole than for us to reclaim sewage and use the water.

Mr. HOSMER. You have not run it out on an existing area or in the new areas, new towns, and so on?

Dr. ELIASSEN. No, sir; but we will consider this in Ventura County, reclaim sewage to use it for irrigation, for instance, irrigation of lawns and things like this, a separate system.

Mr. HOSMER. Los Angeles County is doing a lot of sewage reclamation work.

Dr. ELIASSEN. Yes, sir; John Parkhurst. They are putting Government moneys into——

Mr. HOSMER. They have a big plant, haven't they?

Dr. ELIASSEN. A 10 million gallon a day at Whittier Narrows. They take the sewage——

Mr. HOSMER. This is for the handling of salt water intrusion against underground waters?

Dr. ELIASSEN. Yes. They are spreading it there at the basin and keeping out the salt water this way.

Mr. HOSMER. In connection with salt water intrusion problem you mentioned putting water back in the ground as one of the ways of taking care of it. That is about the only way; is it not?

Dr. ELIASSEN. Stop pumping and have another source. This is what New York has had to do. They stopped pumping and take water from the north.

Mr. HOSMER. That is like dying and giving up.

Dr. ELIASSEN. I agree. Ventura County and Los Angeles County have real problems.

Mr. ROGERS. We may get in a position with all this research to try to equip the human body to drink sea water straight.

Dr. ELIASSEN. That is a real problem, sir.

Mr. ROGERS. Thank you very much.

Dr. T. K. Sherwood, Department of Chemical Engineering, Massachusetts Institute of Technology.

STATEMENT OF DR. T. K. SHERWOOD, PROFESSOR OF CHEMICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. SHERWOOD. I am honored to be here. I am not sure that I can contribute very much except perhaps through your questions. I have no particular ax to grind, but I have a moderately short statement which perhaps I ought to present to you to instigate questions.

Let me first identify myself. I am professor of chemical engineering at the Massachusetts Institute of Technology, and an engineering consultant to petroleum and chemical companies. For some years I was dean of engineering at MIT. I have followed the activities of the OSW since its formation in 1952, and currently supervise fundamental studies of the freezing process at MIT, under a non-profit grant from the OSW. Nonprofit should be in quotes. We appropriate funds from the general funds to make up the difference between the grant and the actual cost of doing this.

I was chairman of the committee of the National Academy of Sciences which planned and organized the 1960 Woods Hole study of research needs for desalination. I have testified before congressional hearings on this subject on several previous occasions. I am concerned primarily with the needs for fundamental research.

I am involved in this subject because I am convinced that the water problem is very real and very serious, and not because I support

research for the sake of research. The most significant water statistic is the rate of consumptive use of water. This refers to water withdrawn from streams, lakes, and aquifers, used once, and then lost by evaporation or in other ways so as not to be available for re-use. The consumptive use of water within the continental United States is not known accurately, but is evidently between 10 and 20 percent of the total fresh water which might sometime be obtained from natural sources by present technology. Not only are the demands increasing steadily, but water supplies vary enormously with time and place, so to me this is a frightening figure. This figure is outside of any water than can be provided by re-use methods.

I am further convinced that desalination is one of the several practical approaches to the problem. Two-thirds of the population lives in the 25 States which border on the oceans, and many of the other 25 States have large supplies of brackish water.

Three desalination processes are now commercial in the sense that companies are prepared to build and guarantee plants. These involve distillation, electrodialysis, and freezing. Small plants having capacities of 1 million gallons per day produce water for \$1 to \$1.50 per 1,000 gallons. Larger plants designed to produce 50 to 100 million gallons per day—enough for the municipal water needs of perhaps 300,000 people—can evidently be built to produce water for 30 to 50 cents per 1,000 gallons. Still larger plants employing nuclear reactors could perhaps produce still cheaper water if the electric power produced simultaneously could be sold at an attractive figure. These costs are high, though they are very much less than desalination costs at the time the OSW started in business.

The desalination program would appear to have two objectives—first, to do better with the processes we have; and second, to discover and develop a new and much better process. The first will be accomplished by engineering—by simpler design concepts, inventions of process modifications, the use of cheaper materials of construction, and the development of more efficient system components. To accomplish these things the engineers will draw on the fruits of the basic research program devoted to materials, corrosion, scale, properties of brines, and on the supply of data basic to the design of the heat and mass transfer equipment which is involved.

It is most important to do better with the processes we now have, if only for the reason that we may never find better ones. Even modest cost reductions would justify the expenditure of a great deal of money for research and development. A cost reduction of only 10 cents per 1,000 gallons would mean a saving of \$73 million in the 20-year lifetime of a single 100-million-gallon-per-day plant.

I am convinced that in the last 10 years since OSW has been in business we have seen a cost reduction of considerably more than this. I would suspect that their efforts are responsible for a fair part of the reduction we have seen. It is very difficult for me, perhaps for anyone, to realize the enormity of this problem.

In answer to one of the earlier questions, it is my understanding that the total water use in this country is on the order of 350 billion gallons a day. This may not be completely accurate.

This is climbing and it is certainly foreseeable we will want 600 to 700 billion in the not too distant future.

If this is so, and if at that time we produced only 35 billion gallons a day, 10 percent of the present, or 5 to 7 percent of the needs of the use of water at that time, then a 10-cent cost reduction in that 5 to 7 percent of the water use would mean an annual saving in this country of almost a billion and a half dollars, so the problem is perfectly enormous.

The other side of the penny is the difficulty of it. The types of processes we have and foresee are not unlike those of chemical and petroleum companies, typical refinery equipment being similar to that we will see in the pilots and demonstration plants.

These companies produce chemicals for 1, 2, 5, 10, 50 cents a pound. Plastics may sell on this range and fine chemicals for much more. We talk here about a product selling for 5 cents a ton. The challenge to scientists and engineers is there.

The second part of the desalination program encompasses the basic research which could lead to a really cheap process. Scientists, engineers, and inventors must be intrigued, stimulated, and supported. New ideas must be tested and promising leads pursued. It is a matter of faith that something enormously important will come of this, but research on similar problems in the petrochemical and chemical industries has shown an excellent payoff record. Research of this kind is a form of gambling, but the odds are excellent.

With regard to industrial research, why don't they do it, there is a distinct difference between the type of operation here and in the operation of the Du Pont Co. which was mentioned, which under the patent system can get something for itself and make a profit which would pay off the research costs.

In this area we are more nearly in the business of building dams, waterworks, and so on, where the possible return through patents is remote. The foreseeable business is largely that of constructing plants and not of developing something unique to the company, so that the incentive for industrial research in this area is not the same as it is in the chemical business.

The OSW receives three to four times as many basic research proposals as it is able to support. Among these could be what we are looking for. The budget of \$4 to \$5 million per year for research is some 40 percent of the total OSW budget for each of the last 3 years. It ought to be larger. But the real trouble is that from time to time it has been deemed necessary to divert research funds to meet the urgent needs of more or less crash programs in the area of engineering and development. One of the principal recommendations of the 1960 Woods Hole study by the National Academy of Sciences was that the research budget be protected against just such raids.

In the light of these observations and convictions, I appeal to Congress to support the basic research program of the OSW, and to suggest ways to protect it against the financial drain of other short-term though doubtless important needs for funds.

The current research program of the OSW is excellent—a nice balance of research on fundamentals and the exploration of novel ideas as to new desalination methods. It is providing technical data needed in the design of plants employing the known processes. It is actively pursuing the very promising new process called “reverse

osmosis." It is a program of the type and quality which justifies continuing support.

I suspect that some Congressmen have felt that basic research was a waste—that the thing to do was to select the desalination process of greatest promise at the moment, and to spend money on its development. This approach will not get us the answer which is really needed. By analogy, we might have concluded 25 years ago that the best approach to the attainment of cheap power was the sophisticated engineering development of steam powerplants. Basic research in nuclear physics could then have been abandoned and we would not now have cheap nuclear energy. Fifteen years ago the Bell Telephone Laboratories might have diverted its funds from basic research to the development of better vacuum tubes—we would then not have transistors today.

In summary, the desalination program has two objectives. The first is to improve the processes we know. The second is to learn enough about water and about separation techniques to devise a new and better process. Both are important. But the second, which depends on basic research, must have what someone has called "patient money"—a continuing stable budget on which to build a first-class research program.

Mr. ROGERS. Thank you, Doctor.

In your establishment, at your school, is any research being done at all on the possibility of rainmaking?

Dr. SHERWOOD. I cannot answer that question. We have a department of meteorology. The head of that department is a well-known meteorologist who has been involved in this area, but my impression is that he and his department are not actively involved in this.

Mr. ROGERS. In the desalination program is any research being done with relation to the manner in which nature does desalinate water in making rain?

Dr. SHERWOOD. I am afraid we are not even up to where we think we understand that quite clearly.

Mr. ROGERS. As I understand it, nature draws this water from the earth in many instances and creates this fresh water. If rain is fresh water and water drawn into the clouds, or created that way—not being a scientist I don't even know the parlance of the field—certainly if the water then becomes fresh it must be desalinated in some way after it is drawn.

Dr. SHERWOOD. The process is almost identical basically with that of both the distillation and the freezing processes in that the water is separated at what we call a phase boundary, the surface of the ocean, liquid below and air above. This is nature's membrane which permits water to pass and not salt.

Mr. ROGERS. One scientist in the early days told me what we needed was a giant kidney.

Dr. SHERWOOD. We hear a lot about spinoff from astronomical and other research. There is a spinoff here in that some of this desalination work is leading to better artificial kidneys.

Mr. ASPINALL. Doctor, I wish to thank you for appearing before the committee again. You were here in 1961 as I recall.

Do you feel personally that you are satisfied with the results obtained from the money we have spent since that time?

Dr. SHERWOOD. I think it is quite remarkable what has happened. If you look at it in the overall picture, one of the effective purposes of the Government program of the OSW has been to stimulate interest in this program. We have done a wonderful job of this.

If you do not look directly at just what the country has done because of this stimulation, thinking about the problem, scientists and engineers are worrying about this problem and inventing right and left. They never would have done it if there had not been a lot of publicity.

Mr. ASPINALL. You were a member of the committee which reported to the President on the program of desalting technology, were you not?

Dr. SHERWOOD. I was a consultant to the group in Interior which wrote that report.

Mr. ASPINALL. Did you propose to them the same philosophy and approach which you have in the statement before us—your main interest is to work on basic science rather than applied science in this field?

Dr. SHERWOOD. The position I took was my purpose in that study. I did that because it appeared to me that I was the one who had to be counted on to do that part, that I was sold on the possibilities of the research gamble toward a new and really different process.

I certainly did not criticize the idea of building modules so as to know how to build a big plant without building one.

Mr. ASPINALL. But you are one of those who still believes there is a possibility of a breakthrough so far as finding new processes to take care of this problem are concerned.

Dr. SHERWOOD. This is a matter of faith, sir. I believe in it, yes.

Mr. ASPINALL. I like to have somebody with faith. I think it is quite a contribution to this hearing, because it seems to me that some of the hardware men are willing now to give up on the scientific mind and just go ahead and build. That seems to be more important in the minds of some people, to build a pyramid and leave it rather than getting down to hard thinking. I am not saying there is not some hard thinking in the hardware field, but there are limitations to hardware. New processes might bring us closer to a settlement of the problem; is that right?

Dr. SHERWOOD. The way I feel about that, Mr. Aspinall, is that the research may lead to a process which is so much better than what we know that we will discard what we know.

On the other hand I have no assurance that this will happen. I did that piece of arithmetic which indicated that even if we have only 5-7 percent, only 35 billion gallons a day, desalinated it would save the country a billion and a half dollars if you cut the cost 10 cents, and this convinces me we just must do both.

Mr. ASPINALL. One of the most important parts of your statement is to the effect that consumptive water needs within the continental United States are not known accurately but perhaps it is around 350 billion gallons per day, but it is evident that between 10 and 20 percent of total fresh water can perhaps be obtained from natural sources by present technology.

That simply means we have in this day between 80 and 90 percent of natural water that could be put to use if we can just get it to the right places. Is that right?

Dr. SHERWOOD. I think you misunderstood me.

Mr. ASPINALL. I want to be sure I understand what you mean.

Dr. SHERWOOD. I haven't the figures with me, but from recollection I believe it is correct that the rainfall in the continental United States is some 4,300 billion gallons a day.

One of the best pieces of literature on the subject of water statistics came from the report of the Select Committee of Aeronautics and Astronautics of the House some 3 or 4 years ago, perhaps 5 years ago.

At that time they stated, as a result of their inquiries, that the water engineers could foresee sometime perhaps getting out of streams and aquifers something like 1,400 billion as the most we can ever get.

We now use 350 billion. Of this 350 somewhere around 100 is this consumptive use that is not available for reuse, and this we can do nothing about. In fact, limitations on reuse will come in because it is necessary to put a certain amount of reasonably fresh water back into the streams.

Mr. ASPINALL. Does your institution have any contract with the Office of Saline Water?

Dr. SHERWOOD. If my knowledge is correct we have five. I think they are all grants. There are three in my department: two of them have to do with membranes for reverse osmosis; the one in which I am involved has to do with both reverse osmosis and the freezing process.

Mr. ASPINALL. Thank you very much.

Mr. HOSMER. You mentioned favorably the OSW research program and you mention the annual expenditures as \$4 to \$5 million and you recommend a larger figure. What figure would you recommend?

Dr. SHERWOOD. I am not competent to suggest one. We discussed this at some length at the Woods Hole meeting some 5 years ago. We concluded that the only way to get at that was to estimate how many first-class scientists could be interested and would work on the program. We guessed 150 to 200 in the country. I am talking now about basic research and not development.

If that guess is right, and you multiply it by a typical cost, including facilities and assistance of \$30,000, you come up with \$5 to \$6 million.

At the present time the problems have expanded so that I feel that is now low.

Mr. HOSMER. On the order of magnitude of \$10 million, roughly double what we have? Would that be a good "guesstimate"?

Dr. SHERWOOD. I would think something like that would be of the right order; yes.

Mr. HOSMER. Certainly it would not be five times.

Dr. SHERWOOD. No; I don't think that you could spend \$50 million a year effectively on basic research simply for the reason of manpower.

Mr. HOSMER. You mentioned the stimulation of inventiveness in the field. I recall there have been other means of doing this. For instance, the British put up a big prize for somebody to come up with a chronometer. In terms of Mr. Di Luzio's fifteen \$50,000 contracts where he gives small prizes in hopes of getting rewards, I am wondering if perhaps we might not establish a \$1-million prize tax free for an order of magnitude invention in this field and stimulate not only the scientific types but the plumbers and other people who might have some contribution to make here. What do you think of that?

Dr. SHERWOOD. I foresee some difficulties. As one whose name has been connected with this program, I receive mail from people who think they have done just this. If we set out to evaluate all of them we would spend a good deal more money than we are talking about here.

Mr. HOSMER. Mr. Di Luzio pays \$100 quite often to get somebody to evaluate some of these proposals so I guess it is not a problem that is not met in a smaller way.

Wouldn't a \$1-million prize tax free stimulate a whale of a lot of thinking in this field?

Dr. SHERWOOD. Unquestionably.

Mr. HOSMER. I have a notion we probably would get a lot more out of it than we would get out of 15 separate contracts. I hope we can provide it if this legislation goes through, provide just such an inspiration.

Mr. WYATT. Your testimony was very helpful to me, Doctor. And I appreciate your appearing. I have no questions, Mr. Chairman.

Mr. ROGERS. Mr. Reinecke?

Mr. REINECKE. Are you aware of any programs that the National Academy is sponsoring to conserve the existing water or cutting down on the daily consumptive use?

Dr. SHERWOOD. I don't happen to know of any.

Mr. REINECKE. Do you feel this would be a reasonable approach to solve the water problem?

Dr. SHERWOOD. I doubt that the National Academy can do anything but collect people and have studies made as to what might be done. They are not an operating organization.

Mr. REINECKE. I realize that. Do you think this is a realistic approach toward this end?

Dr. SHERWOOD. I think there would be another one. I suspect that Professor Eliassen's group and the waterworks people are doing all of these things. HEW; there is a lot going on. Whether another one would be helpful I just do not know.

Mr. REINECKE. Thank you. I have no further questions.

Mr. ROGERS. Doctor, do you have any figures as to how much water it takes for the average person to have a good standard of living in this country similar to that enjoyed by most of us?

Dr. SHERWOOD. I do not have any direct information. I have heard numbers quoted. We use 100, 200 gallons per day per person. I am not sure. It is certainly highly variable depending on whether it is a place where you water lawns, where it is a town with a lot of industrial needs, and so on.

Mr. HOSMER. Mr. Chairman, I have a figure supplied by the Metropolitan Water District of Southern California that an acre-foot of water supplies a family of 5 for 1 year.

Mr. ROGERS. That requires mathematics.

I was hoping to get the answer without having to go through the mathematical computation.

Dr. SHERWOOD. That is about a thousand gallons per family per day. Not quite.

Mr. ROGERS. Thank you very much, Doctor, for your contribution. The subcommittee will stand in recess until 1:30 p.m.

AFTERNOON SESSION

Mr. ROGERS. The Subcommittee on Irrigation and Reclamation will come to order for further consideration of pending business.

The Chair has before it four statements that will be included in the record unless objection is offered; that is the statement of the Struthers Scientific and International Corp., by Mr. John W. Pike, president; statement of the Fluor Corp., Ltd., by Mr. Mark R. Dusba-bek; the statement of the Southern California Edison Co.; the statement of the Metropolitan Water District of Southern California by Mr. Robert P. Will.

Without objection, those statements will be included in the record. (The statements follow:)

STATEMENT OF JOHN W. PIKE, PRESIDENT, STRUTHERS SCIENTIFIC AND INTERNATIONAL CORP.

Mr. Chairman, members of the committee, my name is John W. Pike. I am president of Struthers Scientific and International Corp. of New York City, a subsidiary of Struthers Wells Corp. Our company has participated in the development of freezing—one of the new processes in the art of desalination which the Office of Saline Water has sponsored as part of its research and development program.

Our parent company, for more than a century has been one of the Nation's leading engineers, designers and manufacturers of specialized process equipment for the chemical, petrochemical, petroleum and power industries. Just recently, the Bureau of Mines, U.S. Department of the Interior, in a special study, reported that thermal secondary oil recovery has enabled this country to consider its usable oil reserves at twice the former estimate. By 1980, the Department predicts perhaps 50 percent of all U.S. crude oil production will come from secondary oil projects. Struthers Wells engineers pioneered the development of thermoflood equipment which was introduced for steam flood secondary oil recovery and represents a great contribution to the Nation's conservation program.

As the world's growing water needs become more acute, we evaluated the various approaches possible to produce potable water from sea, polluted, and brackish waters.

Our company has been involved in distillation methods for many years. Struthers has engineered and fabricated distillation plants for the chemical, petrochemical and petroleum refining industries. In fact, we are presently offering distillation plants for water purification based on our background and through an agreement with W. L. Badger Associates, Inc., utilizing the technology developed in the Freeport, Tex., falling film evaporator plant designed by Badger Associates for the Office of Saline Water. Considerable know-how has been obtained from the Freeport plant, and today falling film evaporation is an advanced and mature distillation method which fulfills a specific purpose in our overall capability to provide a broad solution to water needs.

Meanwhile, we reviewed our corporate capabilities and decided that we had sufficient technology to develop a freezing process as a more efficient means to remove fresh, pure water from brine because of freezing's chief advantages: low energy requirements, lower cost plant due to decreased corrosion and no scale formation. We based our work in freezing on more than three decades of technology developed in conjunction with our controlled crystallization engineering for the process industries. More than 30 years ago, we acquired and further perfected the krystal process for growing large, uniform size and shaped crystals. From this technology, widely used in the chemical, fertilizer, and pharmaceutical fields, we have developed methods to grow large, uniform ice crystals which can be easily separated from brine.

We began our efforts at our Warren, Pa., laboratories conducting bench-scale pilot plant research and under an initial grant from the Office of Saline Water about 6 years ago further perfected this method. These developments were the outgrowth of work directed by Hans Svanoë, an internationally known expert on crystallization. He has had a lifelong interest in producing fresh water from the sea, and has built a capable staff around him. Mr. Svanoë is the holder

of many significant patents in the field of crystallization and crystallization processes. Additionally, our staff includes such respected people as Stephen A. Laurich and others we have carefully trained in these techniques throughout our history in the field.

About 1954, similar research work in freezing was started in Japan under the direction of Dr. Shuji Umano. Although the aim of this program was to perfect an efficient method for producing brine for the salt-short Japanese chemical industry, this technology was similar to the work we were doing in the United States. Struthers Scientific acquired the patents and know-how, along with the services of Dr. Umano, during 1962, incorporating this additional capability into our own process. During 1964, we also acquired the rights to patents, know-how, personnel, and research facilities on the Pacific coast at Oxnard, Calif., of the Rocketdyne Division of North American Aviation, Inc. We also obtained by this acquisition the services of Drs. Manuel H. Gorin and Ludwig Rosenstein who have major inventions in the direct contact heat exchange field and other improvements in the freezing process as well as rights to patents developed by Esso Research Corp.

It is this combination of technology, people and facilities which we have put together to continue development work and experimentation to further perfect a new process—freezing—on a broad scientific and engineering basis. Today we have a skilled group which is a nucleus to further broaden our capability. Although we have made much progress in a short time—compared to years available to older heat processes—there yet remains much work to be done. Any program of this type is based on trial and error—what we learn today allows us to take another step forward tomorrow. Progress—scientific progress—can be achieved only through continued developmental work on a meaningful scale by dedicated people bent on success. Sometimes progress has been painfully slow as we have isolated and solved the many mechanical and technical problems inherent in any developmental program of this type.

Much has been accomplished since the Office of Saline Water first began work in this field little more than a decade ago. The cost of producing fresh water by older distillation methods was as high as \$4 per thousand gallons. Today, after 10 years of continued research work, the figure has been reduced to about \$1.

Meanwhile, freezing and other new types of processes—which were little more than ideas 10 years ago—have made strides forward. According to studies and projections of the Office of Saline Water, the United Nations and various learned institutions, the freezing process has considerable promise as a method to produce fresh water from sea and brackish water. Certainly it has the advantage of requiring considerably less energy, in addition to those advantages previously outlined.

We estimate that only \$18 million has been invested toward perfecting the freezing process—about \$6 million has been sponsored by the U.S. Government and the balance by private industry and foreign governments. In terms of major development programs, this amount of money is relatively insignificant. Industry and governments have spent several hundred million dollars on development of and plants for distillation. Combined with the short period of time, we must conclude therefore that considerable progress has been made in developing freezing as a process for economically removing fresh water from substandard sources. Based on this minimal expenditure of time and moneys, it is reasonable to projects significant incremental progress with additional investment.

In the freezing process, much has been learned so that work can go forward. There is still much to be learned. Many of the mechanical problems which are inherent in any new process have been solved. It has been demonstrated that our direct contact controlled crystallization freezing process can produce fresh water, and with further experimentation we can heighten its economics and further perfect its operational characteristics.

Recently, at the 15,000-gallon-per-day pilot plant at Wrightsville Beach, N.C., sponsored by the Office of Saline Water, using our freezing process, pure ice particles as large as one-quarter inch in diameter were produced. This diameter was at least four times larger than contemplated—and demonstrates how major improvements are achieved through development.

Although experimental work on a form of separation—using a centrifuge—has only recently begun, the process has been demonstrated using a wash separation column which has separated one-half ton of ice per hour per square foot from an ice brine slurry—more than ever previously accomplished in a wash column. This piece of apparatus was designed by the Office of Saline Water

from experimental data resulting from one of their research contracts. The results demonstrate how large ice crystals can improve separation efficiency.

These are some of the things we have learned in our experimental, trial-and-error efforts in the pilot plant. We have developed and transferred this information to the larger 200,000-gallon-per-day pilot plant also located at Wrightsville Beach. In the future these concepts can provide the necessary and reliable engineering and economic data from which larger freezing plants may be designed, installed and operated.

Although we have developed an operable freezing process based on one series of criteria, basic research in the new art of freezing remains necessary as in other processes. There are many ideas which, while sound in principle, are only experimental in nature. Engineering and pilot plant experience and analysis are necessary to provide data to decide whether or not to incorporate them into process design of large plants. These programs are vital in the continued experimentation needed to speed development of freezing as an economic, fresh water producing technique.

Freezing also has a unique role to play in brackish and polluted water conversion in the salinity ranges of 9,000 to 20,000 parts per million, as well as in plant sizes for 1 to 10 million gallons per day. For every plant contemplated in the future with a capacity of 100 million gallons per day, we estimate that there will be at least 100 plants of under 10 million gallons per day. Electrodialysis, although suitable for lower salinities, is too expensive in the salinity ranges of 9,000 to 20,000 parts per million. And, because of the typical higher concentration of scale forming compounds in brackish waters, heat or evaporation or distillation processes require expensive treatment to remove these scaling compounds. Freezing, because of low operating temperatures, largely eliminates scale.

Further knowledge can be gained by operating pilot plants of both large and small sizes so that what is learned in small plants can be quickly transferred to a larger scale, or what cannot be done on a trial-and-error basis in large plants can be quickly and economically tested in small plants and transferred if proved correct.

In summary, we believe the following should be accomplished in the coming year to accelerate development of the promising freezing process and that adequate funds be allocated for this purpose:

1. Continued operation of the pilot plants of various sizes to perfect and optimize known process technology and equipment design on an accelerated basis.
2. Programs to develop new equipment designs and process concepts should be accelerated.
3. Continue basic research and development studies to learn more about the physical mechanisms underlying freezing technology.
4. Undertake engineering and economic studies on large-scale freeze desalination plants.

Since this program does not involve design and installation of large plants requiring major equipment procurement during this fiscal year, the expenditures required are relatively small compared with the expected achievements. However, we believe that substantial funds should be provided during the coming fiscal years to achieve the development of a low-cost freezing desalination process.

We, who have invested so much of our own time, effort, money and talent toward building a trained and skilled team and achieving a perfected freezing process, are confident that the President's vision of breakthroughs, and the Department of Interior's dedication and implementation of its program to make available economic pure water throughout the world can be achieved.

Thank you for the opportunity to present these views.

STATEMENT OF THE FLUOR CORP., LTD.

My name is Mark R. Dusbabek, and I am speaking on behalf of the Fluor Corp., Ltd. I have been employed by the Fluor Corp. since 1953, and during that time, I have been directly associated with all of Fluor's sea water conversion and nuclear activities. These activities included the first study performed under the auspices of the Department of the Interior of the applicability of nuclear energy to sea water distillation. That report, completed in 1957, was followed by many others for various clients. In all, Fluor has completed 21 assignments relating to nine different sea water conversion processes, designed what is still the world's

largest combination power and desalting plant, and was responsible for the design of the highly successful Point Loma plant which was subsequently moved to Guantanamo.

The Fluor Corp. is an engineer-constructor serving primarily the petroleum, chemical, and power industries throughout the free world. Our current billings, in excess of \$200 million per year, make us one of the world's largest engineering-construction firms. Until recently, Fluor operated a research division engaged in the investigation and development of processes of interest to industrial clients and public agencies. Some of the processes which we investigated were sea water conversion processes—and some of the work was sponsored by the Office of Saline Water. Although we no longer operate our own research laboratory, we still have research performed when appropriate to further the objectives of our corporation. It is because of this experience that we feel qualified to comment on the proposed legislation, H.R. 7092.

You have asked that we address ourselves to the question of where the responsibility of the Federal Government in this research program ends and the responsibility of private industry begins. Let me first point out that private industry is motivated to undertake research more by the prospect of selling a product for a profit than by a sense of responsibility to attain an objective established by the Federal Government. Therefore, it seems appropriate to examine the objectives of the saline water conversion program in order to form a judgment regarding the nature of future research in this field. In our view, such an examination should begin with a survey of the market for saline water conversion plants. Private industry and the Federal Government might very well approach such a survey from two entirely different points of view. For example, private industry would be inclined to look for a market characterized by an immediate and growing demand for many units. The Federal Government, on the other hand, would be more properly concerned with the imbalance of the national water supply and demand.

It would not be surprising if the results of these surveys were to lead to different conclusions regarding appropriate research programs. We believe that this has, in fact, happened.

For example, several domestic and foreign manufacturers are now offering complete sea water conversion plants on a fixed price, guaranteed performance basis. The capacity of the plants sold to date has in every case been less than 5 million gallons per day although we expect larger plants will be offered on the same basis in the near future. The market appears to be large enough and the competition severe enough to believe that private industry is and will continue to support all the research necessary to assure continuing improvements in the cost and performance of small to medium-sized conversion in plants. Consequently, it is our recommendation that the Federal Government not finance any research directed solely toward the improvements of small plants.

Returning for a moment to the market survey mentioned earlier, let us assume that the Federal Government has discovered a nationwide, or at least, regional imbalance between water supply and demand, requiring an exceedingly large plant to produce very low-cost water. The question is then raised, Can saline water conversion alleviate this imbalance? If it can, only a few such gigantic plants will be constructed. Private industry is not inclined to invest much research effort on such a "one-shot" project, since they cannot be sure the plant will be built, or that they might be assigned the project, should it be authorized.

Here, then, seems to be an area where the Federal Government should support research. Of course, having decided that very large desalting plants may help solve a regional water problem does not immediately dictate a specific research program. Before this can be done, the specific location of such a plant should be established. Next, the nature of the plant to be integrated with the water and power environment of that location should be determined. For example, should or must the plant be single or dual purpose? With this information in hand, conceptual design studies should be undertaken. These design studies should be aimed at reducing costs and improving performance by taking advantage of the unique characteristics of very large plants. Unusual geometries, materials, and construction techniques may prove worthwhile in such large plants.

When these studies have been completed, evaluated, and the optimum design selected, one can begin to devise a research program. That program should be carefully directed at developing the necessary data required to design and assure the successful operation of the optimum plant. Some of this research can probably be carried out in small demonstration plants or modules representing portions of the large plant. The estimated cost of this research should be

added to the cost of the plant when water costs are computed for comparison with alternate water sources. If this total cost makes the cost of converted saline water more expensive than water from an alternate source, then the research program should not be undertaken. In this event, it would seem appropriate for the Federal Government to support research and development on other conversion processes which have, theoretically at least, the potential of yielding acceptably low-cost water, if developed.

In this connection, fundamental research on water properties should be continued since the results of this research will have wide application to all aspects of water supply problems, whether they involve saline water conversion, water reuse, or water pollution.

In summary, we believe that the Federal Government should not support research and development directed at developing or improving conversion processes which are applicable only to small- or medium-sized plants. In addition, we believe that the Federal Government should carefully evaluate the specific use for large plants and base its decision whether or not to proceed with a research and development program on a true economic comparison of the cost of desalted water and alternate water supplies. Since we have not studied (nor are we aware of the results of studies by others) specific applications for very large desalting plants, we can only comment on the criteria which we feel should be used to judge whether or not desalination research and development work should be federally financed.

STATEMENT OF SOUTHERN CALIFORNIA EDISON CO.

The Southern California Edison Co. is a California corporation engaged as a public utility in the supply of electricity in the central and southern portions of the State of California and the western portion of the State of Nevada. The company owns and operates an interconnected steam and hydroelectric generating system located in central and southern California, consisting of 36 hydroelectric stations with a total effective operating capacity of approximately 839,000 kilowatts and 12 steam-electric generating stations having a total operating effective capacity of approximately 5,307,000 kilowatts. In addition, under contract with the United States, Edison Co. has available for its use approximately 316,000 kilowatts of effective operating capacity at the Hoover Dam powerplant on the Colorado River, certain of the units of which it operates as an agent of the United States. The company also owns a small steam-electric generating plant in the State of Arizona which is operated by another utility. The population of the territory served by the company is estimated to be approximately 6,500,000 persons.

SALINE WATER CONVERSION ACTIVITIES

Since 1959 the company has been very interested in the desalination of sea water and has operated a small conversion plant so as to obtain actual experience with desalination equipment of the multiple-stage flash evaporation type. This unit was originally installed at our Mandalay Generating Station near Oxnard, Calif. It has a nominal capacity of 100,000 gallons per day. This unit was built to investigate the feasibility of combining power production and sea water conversion in a single facility. The purpose in investigating this dual purpose concept was based on the reduction in water production costs which can be achieved by the use of low pressure steam for sea water evaporation after partial expansion through the turbine.

Operation of this experimental conversion plant at Mandalay over a 4-year period demonstrated the ability of this type of equipment to perform satisfactorily in combination with a steam electric generating unit and provided valuable information on evaporator operating characteristics and on the serviceability of various materials of construction. Additionally, problems with scale formation and resultant loss of efficiency were investigated during this period and a practical method of scale control developed which permits operation at 250° F. with a 40-percent increase in water production rate and a reduction in product water cost of approximately 20 percent. The water produced by this plant contains less than 20 parts per million of dissolved solids, well below the 500 parts per million design objective established for the Office of Saline Water demonstration plants.

Following this extensive period of testing, a small 750-kilowatt gas turbine-driven generator was installed at the Mandalay station and the conversion plant operated with exhaust heat from the gas turbine rather than with steam extracted from the 220,000-kilowatt turbine generator. This major modification was made to determine the feasibility of this type of dual-purpose plant for application in remote, water-deficient areas which, because of relatively small power and water demand, cannot economically be served by a considerably more efficient steam electric generating unit supplying extraction steam to the water conversion plant.

The company has been specifically interested in this type application because of its responsibility to supply water as well as power for Catalina Island where abnormally low rainfall over the past several years has threatened to create a water shortage. After testing the modified plant at Mandalay for a period of some 8 months, it became apparent that the threatened water shortage on the island would probably develop during this coming summer when the population of the island is temporarily tripled due to the influx of summer residents and tourists. As a result, it was decided to relocate the conversion plant and gas turbine generator to Catalina as rapidly as possible. This relocation was completed early last month and the unit is now producing water at the new location.

In addition to the considerable amount of experience and information which has been obtained through actual operation of conversion plant equipment, Edison has carried out a number of engineering studies to determine the economic feasibility of both intermediate and large-size conversion plants.

LARGE-SCALE, DUAL-PURPOSE PLANT STUDIES

One of these studies was particularly significant since a conceptual dual-purpose plant design with a production capability of 1,500 megawatts of electrical energy and 150 million gallons of fresh water per day was developed in some detail, and the effects of various combinations of financial, operational, and functional plant arrangements evaluated. This study considered both nuclear and oil-fired steam electric generating plants and considered ownership of the water conversion plant by those agencies responsible for water supply and ownership of the power production portion of the plant by those agencies responsible for power supply in the area. The plant design developed by this study consists of 2 generating units, each producing 750 megawatts net to the electrical system and three 38-stage flash evaporators of 50-million-gallon-per-day capacity each, receiving exhaust steam from one backpressure turbine common to both main generating units which can operate with either unit out of service if necessary.

The results of this study indicate that a nuclear-fueled, dual-purpose plant having the specified production capabilities can be expected to produce water at a cost of less than 35 cents per thousand gallons while generating electrical energy at a cost of approximately 5 mills per kilowatt-hour. Since these production costs appear to be economically competitive with those which can be anticipated for future water importation projects beyond the California Feather River project, Edison believes that the possible use of large, dual-purpose nuclear plants located close to the points of water use should receive detailed study and evaluation.

With this in mind, early in the discussions between the metropolitan water district, the Department of Interior, and the Atomic Energy Commission, Edison, and other power-generating agencies in southern California offered to cooperate and assist in any joint study. Power is a part of desalinization and those entities in the power-generating business in southern California felt they could best provide the needed information for such study and evaluation.

This committee is aware that, under the terms of this contract, which was announced in August of 1964, the metropolitan water district assumed overall responsibility for the conduct of an engineering and economic feasibility study of a combination power and desalting plant using a nuclear energy source. An advisory power task force comprised of representatives of the City of Los Angeles Department of Water and Power, San Diego Gas & Electric Co. and the Southern California Edison Co. was appointed to work with metropolitan water district to prepare a realistic basis for marketing electric power produced at the dual-purpose plant.

After a series of meetings with metropolitan water district and its subcontractor, the Bechtel Corp., the three southern California utilities, on April 8, 1965, formally transmitted to metropolitan water district a set of principles for joint participation in the construction, ownership and operation of the dual-purpose power desalination plant under study.

The basic principle involved is that both water and power should bear their fair share of the total plant costs. Power from the dual-purpose plant would cost no more than that which would be produced at a similar single-purpose plant at the same site. Water production would bear the cost of the desalination facilities plus only the incremental cost of additional power facilities needed to produce the additional quantities of steam and power required for desalination operation.

The proposal suggested a plant consisting of two large commercial-type nuclear power generating units, a single, smaller backpressure steam turbine generator, and a multiple-stage flash evaporator desalination plant capable of producing 150 million gallons of fresh water per day. The net electrical capacity of the plant could be in the order of 1,500 megawatts. Each main nuclear steam supply system would be sized to produce the full load steam requirement of its associated main turbine generator plus one-half of the steam required to operate the backpressure turbine generator and the desalination plant at full capacity. The backpressure turbine would furnish desalination plant auxiliary power, power for pumping product water from the site to a point of connection with metropolitan water district's distribution system and supplemental pumping power for metropolitan water district's Colorado River aqueduct. The utilities would utilize all power from the main generating units and would also absorb any surplus power from the backpressure unit. The City of Los Angeles Department of Water and Power and possibly three other smaller municipalities, would own one of the main power units, San Diego Gas & Electric Co. and the Southern California Edison Co. would jointly own the other main power unit, and the metropolitan water district would own the backpressure turbine generator and the desalination facilities. The ownership of common facilities would be assigned to the parties in such a way that the total capital investment by the power entities would be in proportion to their capacity entitlements and would not exceed equivalent single-purpose plant costs.

The proposed arrangement offers metropolitan water district the economy of scale in securing steam from a nuclear heat source and provides the water plant with greater reliability and flexibility of operation than could otherwise be obtained from a single steam turbine generator plant. Preliminary estimates indicated that fresh water could be produced at the plant at a cost of less than 30 cents per 1,000 gallons with power production at a cost of less than 5 mills per kilowatt-hour.

We should also like to emphasize that the two nuclear power generating units included in the proposed arrangement would be of a commercially proven type and that Edison and San Diego would contribute to this project the considerable experience being developed with the large power reactor currently being installed at their San Onofre Nuclear Generating Station near San Clemente.

RESOURCE PLANNING PROBLEM

One extremely important consideration sometimes not given proper weight because the emphasis is put on desalting, is the power features and resource planning aspect. It takes approximately 5 years to design, engineer and construct a large electric generating station and utilities must commit themselves that far in advance to the addition of new generating resources to meet their growing customer demands. In order for power from any dual-purpose plant to have value for an electric utility, it must be planned with sufficient notice to provide for its orderly integration into the utility's planned schedule of resources additions.

CONCLUSION

We appreciate the opportunity to present these developments to the committee and reaffirm our deep interest in the urgent problems of saline water conversion. We offer our continuing cooperation with this committee and would be pleased to keep you informed on any further developments.

STATEMENT OF ROBERT P. WILL, LEGISLATIVE REPRESENTATIVE, THE METROPOLITAN
WATER DISTRICT OF SOUTHERN CALIFORNIA

I appreciate the opportunity to appear before your committee and discuss the desalting plant study begun last December for the Metropolitan Water District of Southern California.

This study, being undertaken jointly with the Department of Interior and the Atomic Energy Commission, is to determine the economic and engineering feasibility of a combination power and desalting plant capable of producing 150 million gallons of water a day. We are indebted to the highly competent staffs of these two agencies for their assistance and guidance and hope to continue to benefit from their abilities and their valuable research work.

Attached to this statement is a copy of appendix A of the study contract which defines the scope of the study. It is being conducted by the Bechtel Corp. and is scheduled for completion by the end of the year. I would like to discuss first some of the reasons which prompted Metropolitan to participate in this study and then describe briefly the progress we have made in these first few months.

The Metropolitan Water District is a public agency responsible for furnishing supplemental water to most of the urban areas of coastal southern California, a region with a population today in excess of 9 million people. This interest of Metropolitan in sea water conversion is not new. In 1959, the Fluor Corp. made a study for us in this regard. Its conclusions at that time indicated that the various processes still required further development and that the district should again evaluate the program in a few years. The district's interest, however, remained active and the reasons which prompted us to consider this new and promising source of water supply have become more compelling as our population spirals upward placing greater demands on our far flung Colorado River water importation system.

As an operating agency, our objectives are most directly concerned with obtaining a significant additional quantity of water for our residents. However, any advancements in desalting technology that may take place are also of great interest to us because of possible importance of desalting in the overall water picture in the arid Pacific Southwest at some time in the future.

First, it must be considered that the period prior to initial delivery of northern California water from the State water project in Metropolitan's service area now scheduled for 1971 may become critical in regard to the sufficiency of available Colorado River water to meet maximum demands for a supplemental supply. If by any chance it should happen that there were any delay in the time schedule for construction of the necessary State and district facilities, an auxiliary source of appreciable magnitude would be of great value. It appears possible that a desalting plant in the capacity range under consideration in our study could be completed and placed in operation by around 1970.

Second, the district's service area is now supplied with imported water through two long aqueducts, the district's Colorado River aqueduct and the Owens River aqueduct of the city of Los Angeles. With the completion of the initial development of the State water project, there will be a third long aqueduct supplying water from a remote source. Each of these three aqueducts crosses the San Andreas Fault which is one of the most, if not the most, extensive and formidable crustal rifts on the entire globe. No cataclysmic disturbance has occurred on the San Andreas Fault since 1906, but geodetic surveys tell us that crustal strains are accumulating to a degree which must be considered significant.

In the event of interruption by earthquake or other occurrence in the supply of water through any of these long aqueducts serving the southern California coastal plain, the question of an emergency supply during the outage would assume critical importance. The available emergency sources such as terminal storage on the various aqueducts, surface storage under the jurisdiction of the various individual water agencies, and groundwater storage are not evenly distributed throughout our service area. Therefore, an auxiliary localized source such as a desalting plant of appreciable capacity which could augment the other emergency supplies would constitute valuable insurance.

Third, the availability of a significant quantity of distilled water would be highly advantageous because it could be used to improve the quality of the district's water supply and make unnecessary the planned installation of water softeners at the district's new 200 million gallon per day treatment plant in Orange County. Mixing distilled water with Colorado River water would not

only improve water quality but would also save some \$15 million in capital costs for these softening units plus softener operating costs of approximately \$4 per acre-foot.

Lastly, as water demands across the Nation increase, it becomes more and more imperative to develop dependable information on the cost of desalting sea water on a large scale. The possible economies to be derived from scale-up in the size of desalting units and in the size of reactors cannot be conclusively demonstrated until a prototype plant has been constructed and operated. In view of the design and construction time necessary before a large plant can become operational, we feel that it is not too soon to consider beginning work on a plant in the size range we are examining.

Since the study got underway in December, some of the guidelines of the scope of work have been made more explicit so as to give Bechtel more precise objectives for analysis. Consideration as to waterplant size has been limited to one producing 150 million gallons per day of water. Light water reactors of the boiling or pressurized water types have been selected for analysis so as to take advantage of the most developed processes. The point of introduction of desalted water into Metropolitan's distribution system has been generally limited to our new filtration plant at Yorba Linda in Orange County.

Further, we have received from three southern California electrical utilities a proposal whereby they would operate the power features of the dual-purpose plant, supplying the necessary steam to Metropolitan for the operation of the waterplant and a small back pressure steam-turbine generator. The power features proposed by the utilities would be double those being studied by Bechtel; they would include two approximately 750-megawatt nuclear power generating units to be financed and owned by the utilities. We will authorize Bechtel to include consideration of this in their work subject to agreement on this point by the Federal agencies.

It is still too early to report any particular conclusions from the study. The initial work has been most concerned with establishing bases to permit proper evaluation of later work, introduction of water into Metropolitan's system, disposal of excess power, and search for a suitable site.

A major portion of Bechtel's time and effort these past 2 months has been devoted to finding a site. Fourteen locations between Ventura County and the Mexican border have been investigated. These have been narrowed to three which are now under more intensive study. Substantial land costs have also prompted an evaluation of possible offshore sites.

Because of the diminishing availability of sites, we intend to give much thought to the immediate acquisition of land for this purpose. We are fully confident that sea water conversion will play a significant part in future southern California water planning and regardless whether the district's board of directors decides at this time to move ahead on the engineering and construction of the plant, we hope to acquire the most advantageous site soon.

The study is still in its preliminary stages, and we will not be able to make an informed decision for some months on whether construction of this plant in the immediate future is justified. However, we have not hesitated to invest a substantial amount of money in this study and we are optimistic about the future of large-scale desalting plants.

APPENDIX A

SCOPE OF WORK

(a) The study to be conducted and reported on by the subcontractor shall be for the purpose of determining the engineering and economic feasibility and preliminary design of a combination power and desalting plant using a nuclear energy source, which plant shall be deemed suitable for operation by the contractor by the year 1970. The study will include an analysis of combination plants with outputs of 50-150 million gallons of water per day and 150,000-750,000 kilowatts of electric power. In order to provide for periodic review and to assure validity of bases for the conduct of work, the study shall be considered to be conducted in three phases as follows:

PHASE I

The first phase shall consist of a preliminary survey of possible sites for producing desalted water and of means for introducing such desalted water into the contractor's system and the economic feasibility thereof; collection and

analysis of water, power, and economic data necessary to establish valid bases for subsequent work; and a survey of the potential market for sale or exchange of the electric power excess to the contractor's needs for its system including its needs arising in connection with the production and distribution of the product of the desalting plant.

PHASE II

The second phase, utilizing data from phase I, shall consist of a detailed investigation, including: an evaluation of nuclear hazards, of not more than three specific sites to be designated by the contractor with approval of the Government; determination of power-water production ratios, operating flexibility, and other plant parameters based on system requirements; conceptual design of sea water intake; an analysis of nuclear reactor systems applicable to the plant requirements; total system optimization including nuclear steam supply and distillation process systems (i.e. coupling parameters); optimization of evaporator design; a comparison of the costs of energy from nuclear and fossil fuels; a breakdown of capital and operating costs of producing water and power at the site or sites selected for further study under this phase II; and a recommendation of the most desirable site and combination plant outputs based on economic and engineering feasibility.

PHASE III

The third phase shall consist of preliminary design and detailed analysis of one combination nuclear plant most applicable to the contractor's system requirements and will include preliminary design and functional specifications; a detailed construction cost estimate based on vendor quotations; detailed breakdown of costs of producing water and power at the selected site as designated by the contractor and delivery of water to a point in the contractor's system designated by it; and proposed arrangements for disposition of electric power excess to the contractor's needs.

(b) The work described in phases I and II of the scope of the study shall be completed and a report thereof submitted to the contractor within 6 months from the date of execution of the subcontract, and a final report covering phases I, II, and III shall be completed for approval of the parties hereto within 6 months following completion of phase II.

(c) The contractor shall arrange for the subcontractor to submit within 15 days after the date of execution of the subcontract a detailed work plan identifying the major efforts to be undertaken by the subcontractor and an overall schedule of the work deemed by the subcontractor sufficient to assure completion of the three phases of the study within the periods prescribed above, which work plan and schedule must be approved by the parties hereto before the subcontractor shall be authorized to put it into effect.

Mr. ROGERS. Our first witness this afternoon—and let me say we are going to move along as fast as possible because we realize that some of you are overtime now and we are going to have to adjourn at 4—is Mr. Charles E. Ennis, assistant to the executive vice president, Catalytic Construction Co.

Mr. Ennis, if you will come forward, we will recognize you.

STATEMENT OF CHARLES E. ENNIS, ASSISTANT TO THE EXECUTIVE VICE PRESIDENT, CATALYTIC CONSTRUCTION CO.

Mr. ENNIS. I am Charles Ennis. As a beginning, I should like to express appreciation on behalf of both Catalytic Construction Co. and myself for the opportunity of appearing before you gentlemen to present our views on the present and projected state of the technology of desalination. Catalytic, as a major engineer-constructor, has a demonstrated interest and indeed a stake in desalting, both from the point of view of early company-sponsored engineering development programs and, more recently, in actual plant designs and economic-engineering studies. We are convinced that desalting is a science as

opposed to an art, and indeed that it is a science reduced at this time to technology.

Mr. Philip Sporn, a recognized authority in power generation who is now intimately associated with various desalting projects, remarked during a recent presentation in New York that "We are as sure of the principles involved in desalting as we are of the multiplication tables." On this premise, then, it is our contention that the basic physical and chemical mechanisms of the distillation processes involved in desalting are predictable, controllable, and well understood. If this premise is accepted, it becomes evident that we are at a point in the reduction of principles to practice where it is necessary that we leave the research scale process and the pilot plant and proceed to a product type plant of a sufficient scale to insure that the economic relationships exist in their true balance.

By this I mean a plant producing sufficient product to guarantee that we do not have an inflated effect of capital cost over operating cost, general cost over maintenance charges or indeed any distortion of the effect of economic parameters.

By the foregoing, I do not imply that today the distillation process, as an example, stands completely refined, fully developed and available in its ultimate form. What I do say is that we have reached a point in the engineering and economic development of desalting by distillation where to make further significant progress it is necessary that we leave the pilot plant and go to the production plant. The basic process is proven; what remains now to be proven is the economic attractiveness of the process.

You may well ask what can be learned in a production scale plant that cannot be learned in a pilot plant—or at least a demonstration plant. If I may be allowed to relate the desalting of water to any other chemical process, I think I can draw some parallels which will be of interest. To quote from an article on "Ammonia Plant Costs" in the February 3, 1964, issue of the Oil and Gas Journal:

In the last 10 years, investment for ammonia plants has been decreased by about 25 percent on a dollar/ton basis.

The decrease in ammonia-plant cost has come about in spite of an increase in overall construction costs. Over the same period the Engineering News Record index for construction costs shows a total increase of about 50 percent.

These cost improvements resulted from a number of factors, not the least of which was improvement in technology in the interim period. However, other significant savings were effected through improved design approaches, better use of available materials and a definite improvement in productivity both in design and construction phases brought about by what is usually termed the "learning curve."

This learning curve concept is no illusory thing. The U.S. Air Force, among others, makes use of the learning curve in contract negotiations, particularly on repetitive work to insure that they reap the benefits of improved productivity. I might cite as specific examples some recent missile installation and modification projects performed by Catalytic. The nature of the work involved, while not directly related to the type of work involved in the construction of desalting plants, is analogous to desalting plant work in that it is highly repetitive. In the case of specific tasks on each of these projects, the improvement in time required for accomplishment and dollar costs is observed and is plotted as

backup for cost negotiations. I would make the point that we might expect a similar improvement in the construction of a production scale desalination plant with the repetitive operations involved in construction of stage bodies, evaporator bundles, pump installations, and so forth.

To return to the specific area of desalting technology, it is apparent that work done to date and principally funded by OSW has made it possible to be much more specific in our approach to reduction in cost of product water. In this respect, I would cite the study performed by Catalytic, with Nuclear Utility Services as a subcontract entitled "A Study of Desalting Plants (15 to 150 million gallons per day) and Nuclear Power Plants (200 to 1,500 megawatts thermal) for Combined Water and Power Production." This study, performed for the OSW and the U.S. Atomic Energy Commission, examined in some detail the interrelationships of the various cost elements involved in production of water. Thus, the results of this study permit the direction of future effort to those areas of plant concept, design, and operation which show the most promise of large unit cost reduction per unit of developmental effort expended. Briefly stated this study indicated that in the distillation type (and specifically multistage flash distillation type) process plants the major cost determinants were external economic factors rather than internal or process-related economic factors. From this we may draw two inferences:

1. The rate of savings improvement in product water cost, would be less from further laboratory scale work on the presently conceived processes than from basic improvements in concept or approach in funding or method of costing energy supplied the plant, and
2. That a production scale plant built today would be fully capable of taking advantage of cost savings made through the latter two courses of approach even though these savings might be made after the plant was constructed and on line.

Still another area of cost improvement lies in the possibility of cost reductions in equipment items which might be achieved only if a relatively large market exists for these equipment items. A large part of the equipment cost in a multistage flash distillation plant is in evaporator surface and pumping equipment.

Considering these separately, it has been said that a 150-million-gallon-per-day plant would require approximately 10,000 miles of evaporator tubing. This is, by an order of magnitude, more tubing in a single order than even the largest tubing manufacturing company's standard costing procedures envisions. To effect full advantage of such a bulk order, it is, from a practical point of view, necessary to actually place such an order. In realistic terms, there is today no incentive for a producer of this material to develop the product availability or even to do the detailed costing exercises in order to get an accurate fix on the cost of tubing in this volume. In considering the pumps involved, we have no doubt that their design and fabrication is within the limits of current technology and capability. However, there is no production experience on such equipment in the size range we are considering and there is no cost experience. The presently active grants from OSW to various pump manufacturers to develop designs and estimating information perform a useful and vital function. However, again we will never know the cost of one of these

pumps delivered to a site ready for use until we actually place an order and see the pumps built and in service.

In very broad and general terms, to consider the current state of multistage flash distillation, I would say that we could predict within plus or minus 10 percent the cost of water from a 150-million-gallon-per-day plant. Notice I say, "cost of water." You have all read in the public press releases from various agencies and organizations wherein predictions are made of water costing anywhere from \$1.25 per thousand gallon to 5 cents per thousand gallons. We can produce water today in existing plants at a cost approximating \$1.25. I feel certain that we will never produce water by the multistage flash process at a cost approaching this by dint of some rather obvious accounting exercises, but the fixed charges on capital investment alone would preclude water production at cost levels this low. The point I would make here is that we feel that major cost improvements achievable through process research and development with the current process concepts have largely been made. Using current process concepts, cost improvements can and will be made through the effect of a construction learning curve, through improvements in unit equipment costs felt to be reasonably anticipated in large orders actually in hand by the manufacturers, and through the benefits expected in operational unit cost reductions in larger plants.

The foregoing, then, presents our views as to the current situation with respect to efforts to reduce the cost of desalting brackish and sea waters. A point of more immediate interest to you gentlemen, however, lies perhaps in our concept of the areas of activity of the Government and of private industry in this overall program.

I stated earlier that in our opinion the major process-related cost improvements in current technology have already been fairly completely exploited in the case of the distillation systems. However, an area in which great promise of significant reduction in product water cost lies is in improvement in basic process and plant concept.

It is, in our opinion, possible to effect appreciable savings in product water cost by a restudy of the basic components of the dual-purpose water desalting power generation plant. However, such a unique approach to the dual-purpose plant concept as envisioned here would require governmental direction for two principal reasons: (1) in all probability present power and water utility regulatory policy would have to be modified to permit the type of plant concept which would yield maximum benefit in terms of cost savings; (2) an approach as unique as that foreseen would, by virtue of its lack of precedent, undoubtedly encounter difficulties in funding from private sources. For these reasons Government sponsorship of some type is seen as a necessity to maintain the program's momentum.

Another major consideration affecting the timing of assumption of major responsibility for the desalting program by private agencies is the degree of confidence existing in the technology of desalting. To explain this statement I believe it is necessary to consider the present status of the Government effort in desalting.

The OSW is recognized worldwide as the leader in the development of desalting technology. Therefore, the course taken by OSW will profoundly influence the course of private participation in desalting projects.

If the OSW continues to operate solely on a laboratory, pilot-plant and even demonstration-plant scale, then private agencies will confine their activities to these levels. Conversely, if the OSW adopts an aggressive stance in the promotion of a production-scale plants, its lead will be followed by a broad spectrum of private industrial and local governmental units. OSW has led the desalting program through process development and confirmation. It now remains for it to maintain this leadership through the intermediate and large-scale plant programs necessary to the economic confirmation of desalting technology.

For as long as OSW indicates a confidence in desalting, private agencies will support and follow its lead.

On the other hand, for as long as OSW refrains from moving into the large-scale plant portion of a desalting effort, private industry will temporize.

I thank you for this opportunity of appearing before your committee and assure you that we at Catalytic sincerely believe in the future of desalting as a practical solution to many of the world's water needs and are eager to continue our participation in this program.

Mr. ROGERS. Thank you, Mr. Ennis, for a very good statement.

Mr. ASPINALL. Do you have questions?

Mr. ASPINALL. Does your company have any contract with the Office of Saline Water?

Mr. ENNIS. We presently have no direct contractual relationship with OSW. We do hold a subcontract from Kaiser Engineers to perform the waterplant portion of the dual-plant study being conducted by the Governments of the United States and Israel.

Mr. ASPINALL. What is your particular duty as assistant to the executive president?

Mr. ENNIS. I am coordinator of my company's desalting efforts. This, of course, includes management of this Israel project currently.

Mr. ASPINALL. Do you have experience in any scientific research work or has it been more in the administrative branch of your operations?

Mr. ENNIS. Generally both. I would say it has been primarily administrative.

Mr. ASPINALL. As I understand your statement, you differ with Dr. Sherwood. You feel that there is no chance of what we have called heretofore a breakthrough, and that now it is simply a matter of perfection of known processes; is that correct?

Mr. ENNIS. No, sir. I would like to clarify that. What I said was that I feel that current technology as applied to the distillation processes and specifically the multistage flash process, appear to be pretty well developed. We feel rather strongly today, and supported by the work we developed in this joint agency study, that there is promise of appreciable cost savings from the million-gallon-a-day plants that we have today in going to plants of 150-million-gallon-a-day capacity.

Mr. ASPINALL. I have just one other question. Why is it that you feel that you must have this competitive influence with the Government working on these particular endeavors before private enterprise will assume or will show an interest and accept the responsibility to go ahead?

Mr. ENNIS. I did not mean to infer a competitive influence. What I am attempting to point out is that the OSW has developed and maintained a position of leadership in this program. As leaders, if they appear to shy away from pursuing this program to its logical conclusion I believe that private industry, and not so much private industry as the companies, agencies, organizations who would own the plants ultimately, will tend to shy away from construction of such plants.

Mr. ASPINALL. You know that there are comparatively large plants in other parts of the world, such as a 2-million-gallon-per-day plant being constructed in St. Croix at the present time because it is found to be feasible and it is the best way of producing potable water. This is being done without any Government association, as I understand it.

Mr. ENNIS. Yes. There is ample precedent for plants of this size. The point I would make is that there is no precedent for a plant of this larger size. We do feel confident that they are feasible.

However, as I say, the leader in the field I think has to continue the position of leadership.

Mr. ASPINALL. Don't you think that the plant at St. Croix would have been built regardless of the operations of the Office of Saline Water, recognizing the fact that some of the members of that Office apparently did not know that it was being constructed?

Mr. ENNIS. This is a judgmental answer. But I would say it probably would have. I would question, perhaps, the timing of it.

I think that the Office of Saline Water's work in the field has perhaps made it possible to go forward with this plant at an earlier date.

Mr. ASPINALL. I would hope so, too, as far as that is concerned.

Don't you think if there is a demand for a larger plant someplace in the United States or in the world in the future that it will be forthcoming?

Mr. ENNIS. Yes. We know of these two specific situations where the economics are such that a plant of this type and this capacity seems to be the most intelligent approach.

Mr. ASPINALL. Thank you very much.

Mr. ROGERS. Mr. Reinecke?

Mr. REINECKE. I have just one question.

You mentioned that your company is working on the United States-Israel joint plan to build a plant.

Mr. ENNIS. Yes.

Mr. REINECKE. What is the predicted cost of this plant and what size plant is it?

Mr. ENNIS. The size range we are investigating is about 175 to 200 megawatts electrical, and roughly 75 to 125 possibly 150 million gallons of water per day. I hesitate to predict for you a water cost.

We are examining three fixed charge rates for one thing. I would say we are talking about water costs in the range of 33 to 42 cents per 1,000 gallons.

Mr. REINECKE. Thank you.

Mr. ROGERS. Mr. Ennis, in reference to your conclusion that the time has come for us to move into the area of 150 million gallon a day, multistage flash process, that we have already developed, is it your conclusion that we know enough from present research in this field that

we could learn more by spending money and moving on into the larger production plant than we could by doing additional research in small demonstration plants?

Mr. ENNIS. With the process we are discussing here, multistage flash, I believe we have reached a point where we have learned most of what can be learned in a demonstration scale plant. The problem now is to optimize the economics in such a plant.

We learned in our study for the OSW and AEC that I referred to in my presentation that the point at which your significant reduction in water cost comes with increased plant size lies, we believe, somewhere in the range of 40 to 60 million gallons a day. What I do feel is that we have to build a plant of this size or larger in order to actually confirm and give us some operating experience in plants of this size.

Mr. ROGERS. And to apply those determinations that we have already made in the demonstration plant.

Mr. ENNIS. Yes.

This technology is unchanged. The technology does not know whether it is applied to a million gallons or 150 million gallon plant.

Mr. ROGERS. You feel until we do move into this area we are going to continue to be more or less in the dark to a certain extent.

Mr. ENNIS. Yes.

I think many of the things we are concerned with now are engineering problems, materials, methods of construction, the optimum discrete producing unit size in the plant and so on.

Mr. ROGERS. Thank you very much, Mr. Ennis, for your presentation.

Our next witness is Mr. W. L. Rogers, vice president, and Dr. B. Keilin, manager, Water Resources Department, Aerojet-General Corp.

STATEMENT OF W. L. ROGERS, VICE PRESIDENT; ACCOMPANIED BY DR. B. KEILIN, MANAGER, WATER RESOURCES DEPARTMENT, AEROJET-GENERAL CORP.

Mr. W. L. ROGERS. I am Bill Rogers, I would like to introduce my associate, Dr. Bert Keilin. I would like to express my appreciation on behalf of Aerojet-General Corp., for this opportunity to testify in behalf of President Johnson's accelerated program for development of water purification processes.

Aerojet-General Corp., has been pleased to serve the U.S. Government, its principal customer, for over 20 years, primarily in the field of national defense. The company has made its greatest contributions over these years in the development of liquid and solid rocket engines, having held major responsibility for engines for the POLARIS, TITAN, MINUTEMAN and many other missiles. Major contributions have also been made on other phases of the defense and space efforts, as a result of which there now exists within Aerojet a technological capability encompassing virtually all phases of scientific endeavor.

Perhaps no group of people are more keenly aware of the tremendous value of fresh water than those of us from the southwestern United States—California, Arizona, and New Mexico. This has been

an area of tremendous population and economic growth in the last 25 or so years. But this could not have occurred without an organized, well-planned and well-funded effort to provide lifegiving water from sources other than natural works.

In the case of California we have seen dramatically how the All-American Canal—a manmade water project—has enabled the southern California area to realize its potential.

To the north, the Department of the Interior's wisely conceived and implemented Central Valley project has made the great California interior one of the most productive agricultural areas in the world.

But what is happening today? The need for fresh, plentiful and cheap water has become a universal need. Not only the arid areas of the Southwest, but the populous areas of New York and the eastern seaboard and many other large metropolitan areas are faced with the area's need for supplementing nature's supply or facing critical shortages which will stifle growth and economic well-being.

The growing need for pure water in the Nation and in the world has been so broadly publicized that it hardly needs further discussion. The 87th Congress demonstrated great foresight in its passage of Public Law 87-295, the Anderson-Aspinall Act, which accelerated the saline water conversion program in 1961. The bulk of the funds expended to date under that act has been devoted to research. As a result, important advances have been made on a broad front. Well-known processes have been improved to an extent that demonstrated costs in desalting water are substantially less than those which obtained prior to the passage of that law.

Virtually unknown processes have been developed to a point where further sizable cost reductions in water conversion are in sight. In all, the achievements in saline water conversion have been well worth the cost.

But now research accomplishments of yesterday and today must be channeled into engineering development phases, which are inevitably more costly.

The bill now under consideration by the committee will provide the incentive and necessary support for progressive pursuit of the objectives. This bill has the unqualified endorsement of the Aerojet-General Corp.

The history of the reverse osmosis process, and the roles of the Office of Saline Water and the Aerojet-General Corp. in its development present a typical example of a process brought from virtual anonymity to the threshold of fruition. Also illustrated in this example is the efficient operation of the Government agency-industry team in bringing about the achievement.

Aerojet-General's relationships with the Office of Saline Water have been uniformly productive. Since award of our first contract in reverse osmosis by the Office in July 1962, their resourceful management of the program has provided helpful guidance and encouraging stimulation for our technical staff.

About 5 years ago, the Aerojet-General Corp. undertook to diversify its product line into areas not associated with national defense. Geared to carrying out services under contract to the Federal Government, and ever responsive to national needs, the company initiated its efforts in desalination by sponsoring an intensive study of methods

for water purification. These studies indicated to us that the reverse osmosis process was sufficiently outstanding among the less developed processes to warrant intensive examination. Subsequent study in research, development and equipment fabrication has fortified our original conviction so that we now believe that for many applications, the reverse osmosis process will provide the lowest cost manufactured water for the future. This work has been carried out both with company funds and with support from the Office of Saline water.

In the reverse osmosis process, a synthetic membrane, similar to cellophane, selectively permits the passage of water (through the membrane) but does not permit the contaminating dissolved materials to pass through. Thus, a contaminated feed stream flows under pressure across a membrane surface whereupon potable produce water is obtained on the downstream side of the membrane, a concentrated reject stream remains behind and is discarded. The membrane is the key to the process, acting virtually as a magic door permitting the passage of that which it is desired to recover, rejecting that which it is not desired to recover. The driving force is the pressure applied.

Prof. C. E. Reid, under contract to the Office of Saline Water, demonstrated that of all known membranes, only cellulose acetate (rayon) film exhibits adequate separation efficiency for an effective process, but at low throughput per unit membrane area. Somewhat later, Dr. S. Loeb, at the time a graduate student at UCLA, modified the process for fabrication of cellulose acetate membranes to enhance the water throughput rate to economical levels while still retaining a sufficiently high rejection of the dissolved contaminants to render the product potable. Shortly afterward, Aerojet-General undertook to improve the performance of these membranes, to develop new and better membranes, to demonstrate the feasibility of reverse osmosis in the field and to design low-cost equipment for economical application of the process. As a result, important advancements in the state of the art have been made, both in membrane improvement and in pilot development of the process.

The unique membranes utilized in the reverse osmosis process resist the passage of the most dissolved contaminants. As a result, the process promises to be useful in a variety of applications.

The rejection of ordinary salinity (the major sea water contaminant) and of hardness, scale and alkalinity factors (predominant in many brackish waters) makes its use obvious for purification of these waters. Furthermore, the membrane holds back organic matter (which is a major constituent of waste water and includes detergents). The membrane also rejects bacteria and viruses so that the product is sterile. Mine drainage water may also be purified by this process as well as water contaminated by chemical, bacteriological and radioactive agents.

Specialized military uses include production of drinking water and boiler feed water; recovery of photographic wash water and laundry water; and disposal of shipboard wastes in harbors.

Virtually all of the advantages of the reverse osmosis process derive from its room temperature operation. There is required no intermediate formation of steam or ice which, for the distillation and freezing processes, respectively, leads to the expenditure of large

quantities of energy. Reverse osmosis, on the other hand, requires only pressurization energy and the energy cost is relatively low. Furthermore, there is virtually no scaling and a little corrosion, as a result of which the maintenance costs are projected to be low; these advantages combine to promise a low total operating cost.

A further advantage of the room temperature operation is that the designer is able to use plastic materials, which are not capable of withstanding the high temperature demanded by the distillation processes. This use of plastic materials enables the use of inexpensive fabrication techniques which lead to lower capital costs, and hence lower taxes, interest and related general costs.

In developing the reverse osmosis process to its present state Aerojet's efforts have not been limited to the laboratory. One of the most important steps in the development of any chemical process is that first one, which moves the process from the lab into a working, field model. This step, again with the helpful guidance and funding of the Office of Saline Water, has been achieved with great success. Engineering experiments have been carried out in a 1,000-gallons-per-day pilot plant, operating on various brackish waters containing 5,000 parts per million (0.5 percent), for over 2 years. The work has culminated recently in a continuous 5½ month test, exhibiting low maintenance and operational requirements. Operations on sea water at the 1,000-gallons-per-day level have recently been initiated. On a smaller scale, the utility with sewage waters has also been demonstrated under contract with the Public Health Service.

The program has been of such high success that the project is ready to proceed to larger experimental plants. With the support of this committee and of the U.S. Congress for President Johnson's program, the Aerojet-General Corp. is prepared to serve the Office of Saline Water by construction of a 50,000-gallons-per-day experimental plant to operate on brackish water. This could be undertaken immediately and awaits only available funds.

Similarly, we expect shortly to be ready to move ahead in the area of sea water purification on a larger scale. The renovation of sewage wastes is now ready to be moved from the laboratory where it has had a most successful preliminary feasibility study and into the field of a 1,000-gallons-per-day plant to demonstrate utility in actual operating conditions just as has already been done in the brackish water applications.

There is yet much to be done in improving the reverse osmosis process. Research on new membrane systems can be expected to provide improved performance and economy. It is our belief that, with support of this program by the Congress, major improvements will be effected in the state of the art of desalination technology by the reverse osmosis process.

Aerojet's efforts in exploitation of the reverse osmosis process for purification of water are not limited to our work for the Office of Saline Water. We now have market analysis, design, development, and construction of prototype equipment underway with our own funds aimed at commercial application in areas to which we feel the current state of the art can be extrapolated; that is, up to 10,000 gallons per day.

I would like now to say a few words about a question of interest to all of us, I am sure—where does the responsibility of Federal Government in this research program end and the responsibility of private industry begin?

I feel that the taxpayers' funds should never be spent in areas where private industry can meet the public's requirements on time at a reasonable cost.

The reason for the Government's entry into water desalination research, and a good and sufficient reason in my mind, is that in the face of an ever-increasing need for fresh water in many parts of the United States and the world, private industry, because of the status of development of available processes, is not able to satisfy this need in terms of availability and cost.

Progress has been made—more than sufficient progress, I think—to prove the wisdom of the Anderson-Aspinall Act. But more work is required to achieve the act's far-seeing objectives.

The responsibility of the Federal Government in this research program should end as soon as private industry is in a position to shoulder the burden in a given area. This time will come when definition of the specific market, available technology, and acceptability of the risks involved enable private industry to design and sell products at a profit. Competition will then force industry to perform research and development to improve its products to maintain its position in the marketplace.

I submit that the strength of the American free enterprise system, the constant search for new products which are the lifeblood of any firm, and the demonstrated willingness of private industry to take substantial risks when the market, technology, and resources are in balance provide adequate assurance to the members of this committee that governmental support will not be carried beyond the point required to serve the best interests of the public.

Thank you, gentlemen.

Mr. ROGERS. Thank you, Mr. Rogers.

Mr. Aspinall.

Mr. ASPINALL. Mr. Rogers, I hardly believe it is necessary for me to ask this question, but you do have present contracts with the Office of Saline Water?

Mr. W. L. ROGERS. Yes, sir.

Mr. ASPINALL. Could you give to this committee the amount of money that you have received throughout the years from the Office of Saline Water?

Mr. W. L. ROGERS. Yes, sir. To June 1965, it is \$1.34 million.

Mr. ASPINALL. How many employees of your company do you have at the present time who are assigned to this particular work?

Mr. W. L. ROGERS. Twenty.

Mr. ASPINALL. On page 2 you say it is necessary to provide life-giving waters from sources other than natural works.

By that you meant other than just having it fall and be diverted by dams or something like that?

In other words, the necessity of carrying water long distances. Is that what you meant?

Mr. W. L. ROGERS. That means in that context other than nearby streams and closely available things.

Mr. ASPINALL. Or lakes, as we call them.

Mr. W. L. ROGERS. Yes.

Mr. ASPINALL. I just wanted to be sure.

On page 4 you say studies indicated to you that the reverse osmosis process was sufficiently outstanding among the less developed processes. What are the less developed processes that you had in mind?

Mr. W. L. ROGERS. In addition to the reverse osmosis process, ion exchange is one. Freezing is, or was less developed at that time than distillation-extraction.

Mr. ASPINALL. What you mean is that reverse osmosis or the ion exchange is the only new one we have had in centuries and this is the one which you think has the best chance for success.

Mr. W. L. ROGERS. As Mr. Di Luzio said yesterday, reverse osmosis goes all the way back to Aristotle, so in one sense it is not really a new process.

We are talking about those which at the time when we started looking at this field were less well developed than the others.

Mr. ASPINALL. On page 5 you call to our attention the development in the reverse osmosis program. It is your contention that if you had not had contracts and help from the Federal Government that these steps of progress would not have been made, is that right?

Mr. W. L. ROGERS. Certainly at the time they were available, sir.

Mr. ASPINALL. On page 7 you suggest that with the support of this committee and the Congress for President Johnson's program, you do not mean to imply that this is just a new program? What you mean is that President Johnson has picked up President Truman's and President Eisenhower's and President Kennedy's previous programs which were originally given to the President by the Congress and is now advocating the same program, is that right?

Mr. W. L. ROGERS. Yes, sir.

This year it is President Johnson's program but it is also really an extension of the Anderson-Aspinall bill.

Mr. ASPINALL. Before it gets through, Mr. Rogers, it will either be or not be the program of Congress. I just wanted you to understand that we are not about to give up the leadership we have taken in this program heretofore.

Mr. W. L. ROGERS. That is clear to me, sir.

Mr. ASPINALL. On page 9 you set forth your philosophy as to when Federal Government should get out and private enterprise take over entirely.

I think your statement is a fine statement in a very few words. But as I understand it, you have competitors in this field who think that it is about time the Federal Government was getting out. Do you want to say anything more or do you just rest on your statement?

Mr. W. L. ROGERS. I think I will rest on my statement, sir.

Mr. ASPINALL. How much has your company expended on the desalting program other than the money which has been made available to you from the Federal Government?

Mr. W. L. ROGERS. \$765,000 through June of this year.

Mr. ASPINALL. Could a reverse osmosis desalting plant be operated economically on off-peak power?

Mr. W. L. ROGERS. I am going to ask Mr. Keilin, who knows a lot more about these things than I, to answer that question.

Mr. KEILIN. Yes, sir. Reverse osmosis essentially works on electrical power. Off-peak power is generally considered to be less expensive than peak power, and therefore the economics would improve on off-peak power.

Mr. ASPINALL. It can be said to work on pressure alone, can it not, without power applied?

Mr. KEILIN. No, sir. The pressure is obtained by the use of electrical power. Pressure is obtained by pumps which are run by motors which utilize electrical power.

Mr. ASPINALL. I am not going to argue with you. I am not a scientist. I understand all you have to do is to have pressure to throw your water through the membranes. This does not necessarily have to be furnished from power from electricity. It may be furnished through other forms of power.

Mr. HOSMER. Would you yield, Mr. Chairman?

Mr. ASPINALL. Yes.

Mr. HOSMER. If you use off-peak power, say for 12 hours a day, or half a day, and you require a certain amount of production of fresh water—if you limit yourself to off-peak power you have to double the amount of membranes, is that right?

Have you reckoned that out against cost of on-peak power, and if so, is it the high-cost power or low-cost power where you gain your advantages, and so on? As I understand it, what you imply is that you always are in the situation where you double or increase the amount of desalting machinery rather than go into peak power hours and cost.

Mr. KEILIN. We are in the same situation as all other desalting processes. The cost of power is what affects the final cost of the water.

We have generally made our calculations based on the OSW standardized procedure.

Mr. HOSMER. You really have not gone into this area of the economics that you tried to give Mr. Aspinall an answer about, have you?

Mr. KEILIN. Excuse me, sir, I do not understand the question.

Mr. HOSMER. You really have not gotten that deep into the economics, use of peak power versus increase of the capacity of the facilities?

Mr. ENNIS. That is right.

Mr. HOSMER. You have not mentioned the possibility of building a water tower and pumping off-peak into the water tower as well as running your machinery and using the pressure in an on-peak hour, and so forth. You did not tell them that. You have not explored that.

Mr. KEILIN. We have not made that exploration.

Mr. HOSMER. That is what Mr. Aspinall wanted to know and I do not want to be misled on it.

Mr. REINECKE. As a quantitative figure, what are the pressures we are talking about across the membranes?

Mr. KEILIN. 1,500 pounds per square inch for sea water.

Mr. REINECKE. 1,500 p.s.i.?

Mr. KEILIN. Yes.

Mr. REINECKE. This would make a tower very difficult.

Mr. ASPINALL. We will have another witness on that pretty soon. How much money do you think will be needed to bring the reverse osmosis process to the point where it is ready to be tested in a large plant, say a 1 million gallon per day or more?

Mr. ENNIS. I do not have that figure in mind. I know we have submitted a proposal to the Office of Saline Water for a 50,000-gallon-per-day plant—a pilot plant—which is in the amount of \$950,000.

Mr. ASPINALL. You are not the only contractor of the Office of Saline Water in this particular field; are you?

Mr. W. L. ROGERS. No, sir; we are not.

Mr. ASPINALL. Is this process in your opinion competitive at the present time or will it be competitive with the electrodialysis process? Are the membranes similar?

Mr. W. L. ROGERS. There are several questions. First our experience to date—and I want to reemphasize this—is in a 1,000-gallon-per-day pilot plant. So any final discussion of what is competitive and what is not must await the time when we have comparable plants of comparable size. We think it has great promise for being competitive.

The last question about the membranes I will ask Mr. Keilin to answer.

Dr. KEILIN. The membranes are quite a bit different.

Mr. HOSMER. Some people seem to think that you haven't done much work yet on the problem of holding the membrane in the relation to the progress your competitors have made.

Mr. ROGERS. The problem of holding the membrane?

Mr. HOSMER. Yes.

Dr. KEILIN. The method of holding the membrane which we use, we have confidence, we have demonstrated the useability in a five-and-a-half-month test completed recently on the thousand-gallon-per-day size. I am not aware of these statements that you mention, but we would welcome a discussion or mutual exchange of ideas with people who think otherwise, at any time.

Mr. HOSMER. Do you people exchange information among each other or does it go to the Office of Saline Water?

Dr. KEILIN. We submit our reports to the Office. We do not have today day-to-day contact with our competitors, but each of us has a job to do, and we have to concentrate on getting that job done.

Mr. HOSMER. You come to a scientific meeting occasionally and if you run into somebody from GA, you try to pick their brains?

Dr. KEILIN. Naturally.

Mr. REINECKE. Do you have any approximation of the cost involved?

Dr. KEILIN. Actually the energy essentially which it takes to pressurize, with these low flows we believe will prove to be quite small compared to the energies required in the distillation process. We are projecting 34 kilowatt-hours per thousand gallons as the energy expenditure in a sea water plant.

Mr. REINECKE. For electrical?

Dr. KEILIN. Yes.

Mr. REINECKE. 34 kilowatt-hours per thousand gallons?

Dr. KEILIN. Yes.

Mr. ROGERS. Thank you very much, gentleman.

Our next witness is Mr. Philip D. Bush, vice president, Kaiser Engineers.

STATEMENT OF PHILIP D. BUSH, VICE PRESIDENT, KAISER ENGINEERS

Mr. BUSH. Thank you for the opportunity of being with you today. I have forwarded to you earlier a report which I will not read, but which will serve as reference material for many of the remarks that I will be making.

Mr. ROGERS. Do you desire this statement to be placed in the record?

Mr. BUSH. Yes.

Mr. ROGERS. Without objection, it will be included.

(The statement follows:)

STATEMENT OF PHILIP D. BUSH, VICE PRESIDENT, KAISER ENGINEERS, DIVISION OF KAISER INDUSTRIES CORP.

Mr. Chairman and members of the committee, my name is Philip D. Bush. I am vice president of Kaiser Engineers, Division of Kaiser Industries Corp., with headquarters in the Kaiser Center, Oakland, Calif. I have been actively engaged in plant operation, process engineering and construction for 26 years, of which 22 years have been with the affiliated Kaiser companies. Specific experience has encompassed the following industries: steel and its byproduct chemicals, aluminum, cement, gypsum, metal products, nuclear energy, space, and desalination.

My purpose in appearing before you is to bring to your attention examples of how U.S. industry, by increases in equipment and plant sizes and/or technological changes, has been able to increase productivity and reduce unit costs dramatically. In some cases, this has been brought about by startling technological breakthroughs; but in most cases, the results have been obtained by a series of significantly large "stepwise" increases in size or a combination of several process improvements. The statements which follow include actual examples of the above ideas as they pertain to those industries in which the author is well versed.

INTRODUCTION

Kaiser Engineers, serving as engineer-constructors to the Kaiser affiliated companies, and worldwide industry as well, has contributed to and is familiar with the means by which the basic raw materials, process and manufacturing industries have effected unit cost reductions by means of technological change and increased plant or equipment capacity.

Kaiser Industries Corp. includes among its affiliated companies producers of aluminum and refractories, steel, cement, and gypsum. These industries require the chemical processing of billions of pounds or gallons per year of naturally occurring raw materials. Kaiser Aluminum produced over 1 billion pounds of product, Kaiser Cement & Gypsum produced over 7 billion pounds of product, and Kaiser Steel nearly 5 billion pounds of product in 1964.

The Refractories Division of Kaiser Aluminum & Chemical Corp. in 1964 processed 30 million gallons of sea water per day for recovery of magnesia for refractories.

In these basic industries the history of the manpower used, process improvements made, and increases in component, module and plant capacity, and their effect on product cost may be used as a basis for predicting the future trends of the desalting industry.

For example, the maximum size grinding mills in the cement industry in 1955 was 1,500 hp. Larger size mills may have been more economical in 1955, but no one knew how to design and build them. An intensive development program has now raised the maximum size of this important component to 6,000 hp. The amount of capital cost saving per barrel of capacity and increase in grinding efficiency are impressive.

The nuclear power industry is another example where technological improvements have produced recent startling results. The past 2 years have changed the competitive nature of fossil-fueled and nuclear-fueled plants. Oyster Creek, Dresden No. 2, Niagara Mohawk, and Los Angeles Malibu are new powerplants using nuclear energy rather than fossil fuel on the basis of economics.

These examples illustrate the kind of data I believe are pertinent to desalting. While the interaction between manpower reductions, process improvements, increases in plant capacity, process efficiency, and technological advancement is complex, a look at the separate categories reveals the gains which have been made and indicates those which are possible in related industries.

I have chosen to present the data on aluminum and refractories, steel, cement, gypsum, and nuclear power in four sections:

Section I tabulates the manpower required per thousand pounds of product (which represents one component of product cost), and discusses how some of these gains were made.

Section II gives specific examples of process improvements in these industries showing the effect each has had on the cost of the product. These improvements are rarely foreseeable or predictable exactly as to timing or magnitude. They occur in both new and well-established industries; they can be expected in a fast-moving industrial technology.

Section III lists the history of unit-energy consumption in several of these industries, this being an important element of product costs affected by advancing technology.

Section IV shows the dramatic effect of module size changes in the cement industry, electric utility industry, and steel industry, and the effect they have had on capital costs.

These four sections present data representative of basic industries processing large quantities of bulk raw materials—industries whose process philosophies are similar to those of an industry devoted to desalting water.

SECTION I. TRENDS IN MANPOWER REQUIRED TO MANUFACTURE VARIOUS PRODUCTS

At the turn of the century, aluminum was an infant industry producing small quantities of a high-priced product. The early history of the price per pound and the annual production of the aluminum industry is a good example of how production quantity and costs are related as an industry matures. Table 1 illustrates the marked early price reduction, and the continuing increase in annual production which occurred. The data spans 60 years during which time there were many business cycles and external economic changes, yet the data show an overall downward trend in costs.

TABLE 1.—*History of aluminum primary ingot prices*

Year	Price per pound	Annual production 1,000 tons per year
1886	\$8.00	
1889	2.00	
1893	.75	2
1918	.33	60
1925	.28	70
1930	.24	110
1935	.21	40
1940	.20	180
1945	.14	600

Table 2 shows the manpower requirements per thousand pounds of product. Even in such mature industries as those listed, reductions are still taking place. For instance, the figures for aluminum show a 50-percent reduction in the 12-year period between 1950 and 1962.

A specific example, Kaiser's Baton Rouge plant processes bauxite into alumina (the basic aluminum oxide from which aluminum is produced) using huge quantities of steam and soda in chemical digesters.

TABLE 2.—Trends in manpower requirements to manufacture various products; reductions result from increased equipment and plant sizes as well as from process technology changes

[Units are man-hours per 1,000 pounds of product]

Year	Aluminum industry average	Kaiser Aluminum & Chemical Corp.		Kaiser Cement			Kaiser Steel
	Aluminum	Alumina—Baton Rouge plant	Magnesia—Moss Landing, Calif.	Cement			Steel—Fontana, Calif.
				Plant A	Plant B	Plant C	
1949	13.9		2.6				
1950	12.7						
1951	13.1						
1952	13.3						
1953	13.6						
1954	12.1		1.1				
1955	10.8	2.3					
1956	10.3						
1957	10.2						6.8
1958	8.9			0.50			6.4
1959	7.7		.7	.50			5.6
1960	7.2			.50	0.37		6.4
1961	6.9			.50	.37		5.4
1962	6.6			.50	.37		5.6
1963				.25	.37	0.30	5.0
1964		.9		.25	.37	.30	4.5

Source: U.S. Department of Commerce.

The manpower requirements at Baton Rouge have been reduced by 60 percent in the last 9 years as shown in column 3 of table 2. This was accomplished in a 20-year-old plant by process improvements such as raising the digester temperature to 400° F., increasing the capacity of some components and by making a modest increase in plant capacity. More economical forms of caustic soda are now used; a substitute has been developed for cornstarch and a new source of lime has been developed. These process improvements and corresponding manpower reductions have resulted in almost a 50-percent reduction in the cost of producing alumina.

Kaiser's magnesia plant may be of even more interest because of the use of sea water as a raw material. At Moss Landing, Calif., Kaiser refractories operates a plant to produce magnesia and periclase, materials which are used primarily in the manufacture of basic refractories. Since the plant was built in 1942, a number of major additions and improvements have been made. Column 4 of table 2 shows the steady decline in man-hours worked per 1,000 pounds of plant production for 5-year intervals.

The Kaiser Cement data illustrate the results of technological advances made as new plants are built. Plants A, B, and C are three Kaiser cement plants built in sequence 2 or 3 years apart:

1. Each of these plants was initially designed for the same capacity, but the man-hours required per pound of cement have been reduced by 40 percent between 1958 when plant A was built and 1963 when plant C was built.

2. At plant A the capacity was doubled in 1963 by an increase in grinding mill size from 2,000 to 4,000 horsepower per mill, and an increase in kiln size from 12-foot diameter by 450 feet long to 16-foot diameter by 520 feet long. The only increase in men needed was 5 percent for quarrying and shipping.

3. Plants B and C are the same capacity but reduced manning requirements reflect technological improvements such as better layouts and centralization of equipment control.

	Plant B— built 1960	Plant C— built 1964
	<i>Men</i>	<i>Men</i>
Quarry including crushing.....	11	7
Mills, kilns, plant labor.....	26	16
Mechanical and electrical maintenance.....	14	16
Total.....	51	39

Table 2 also shows the reduced manpower for Kaiser Steel's plant at Fontana, Calif. Kaiser's process improvements which are typical of those within the steel industry include many items described in the next section, but the effect on man-hours per thousand pounds of finished steel is a good measure of the continuing process improvements and equipment modifications still taking place in one of the oldest of industries.

SECTION II. PROCESS IMPROVEMENTS IN SPECIFIC INDUSTRIES

A. Aluminum production

Kaiser Aluminum & Chemical Corp. is a fully integrated producer of primary aluminum and fabricated aluminum products. Since Kaiser Aluminum entered the aluminum business in 1946, it has made significant progress toward lower costs through innovation, technological change and size scale-up of various unit operations.

Aluminum ore, called bauxite, consists of alumina, present as a hydrated oxide, together with various impurities. The reddish bauxite ore, mined by open pit operations, is shipped to alumina plants where it is refined into pure granular aluminum oxide (alumina).

The alumina is then dissolved in molten cryolite (sodium aluminum fluoride) contained in shallow, carbon lined steel tanks known as reduction pots. As electric current passes through the alumina-cryolite bath, the oxygen of the alumina combines with the carbon lining, molten aluminum is produced and collects in the bottom of the pot. The molten aluminum is periodically siphoned off and poured into molds to form ingots.

Kaiser Aluminum fabricating facilities roll, forge, and extrude the basic metal into a variety of products, which are distributed nationally and internationally to industrial and certain consumer markets.

Alumina.—In 1949, Kaiser acquired the Baton Rouge alumina plant which originally was designed to handle high-grade bauxite of the trihydrate type. These trihydrate bauxites were generally expensive to mine and ship and their occurrence and ownership were quite limited. During the period from 1948 through 1953, Kaiser explored and developed deposits of Jamaican bauxite as a major source of raw material.

The standard trihydrate (Bayer) process, which is used in this country for refining Surinam (Dutch Guiana) bauxite, was unsuitable for processing the mixed monohydrate-trihydrate Jamaican bauxite because of the appreciable losses in the form of unextracted monohydrate alumina. Kaiser modified the Baton Rouge plant to handle the Jamaican bauxite. This involved a novel process with higher operating temperatures, pressures, and flows, and resulted in greatly reduced alumina costs for Kaiser.

In 1955-56, further process improvements were made in the design of the alumina plant at Gramercy, La., to process Jamaican bauxites even more efficiently. Temperatures were raised to 470° F. (compared with 300° F. for the original Baton Rouge design, and 400° F. for the Baton Rouge plant after modification). Special large valves and piping systems were developed. The Gramercy plant was the largest single-unit alumina plant ever built when completed. The new Gladstone, Australia plant of Queensland Alumina Ltd. (jointly formed with three other participants in which Kaiser Aluminum owns 52 percent) will be even larger, continuing the trend.

To see the effects of these technological improvements, let's take the Baton Rouge plant as an example. In 1955, the plant employed a work force of 1,800 people to produce 830,000 tons per year of alumina. The same plant today makes 940,000 tons per year, while the work force has been reduced to less than 800 people. Ground sorghum has replaced refined cornstarch as a settling aid; liquid caustic soda has taken the place of dry soda ash as a raw material; lime is produced from raw oyster shells dredged from Lake Pontchartrain. Alumina

costs from today's most modern plants are only one-half to two-thirds of costs per ton 10 years ago

Aluminum reduction.—The trend in reduction cell design has been toward higher amperage operation with consequent increases in the physical dimensions of the cells. At the same time, advances in operating techniques and designs have led to more efficient cell layouts with the result that the production per unit floor area has increased markedly.

The design of a reduction cell is complicated by numerous hardware problems (anode clamps, electrical connections, jacking mechanisms), selection of proper materials of construction for cell linings and collector bars, and unknown magnetic effects. As a result, progress from smaller to larger cell designs usually follows the "slow-and-steady" route of relatively small changes followed by periods of operation during which the "bugs" are worked out. However, the rate of change is increasing, as evidenced by the following Kaiser Aluminum experience:

A. Cells using Soderberg-type anodes

Plant	Year	Cell electric current amperes
Tacoma, Wash.:		
Original design.....	1942	32,000
First modification.....	1947	38,000
Experimental addition.....	1952	55,000
Chalmette, La.:		
Original design.....	1950	64,500
Modifications.....	1965	71,700

B. Cells using prebake-type anodes

Plant	Year	Cell electric current amperes
Mead, Wash.:		
Original design.....	1942	50,000
Gradual improvements (increased cells per line from 130 to 140 and added 2 lines).	1946 to present.....	64,500
Ravenswood, W. Va.:		
Original design.....	1957	78,000
Modifications.....	1965	86,500
Volta Aluminum Co., Ltd.: Design and prototypes.....	1965	150,000

Along with the increases in the size of each cell have come increases in the number of cells per line and lines per plant, which also have the effect of lowering unit capital and operating costs. These improvements have generally held the primary metal production cost steady in the past 10 years in spite of increases in labor, materials and energy costs.

Raw materials.—A third area in which primary aluminum producers have been able to reduce or stabilize costs is in raw materials and process supplies. Efforts here fall into several broad categories.

1. Utilization of waste materials: an example is the use of fluosilicic acid waste from the Florida phosphate industry as a raw material for cryolite.

2. Replacement of higher cost with lower cost materials: for example, use of ground sorghum instead of refined cornstarch has reduced operating costs by \$1 million annually.

3. Integration of raw materials manufacture with primary processing where attractive purchase arrangement cannot be made. An example is Gramercy where the boilers required for steam production for the alumina plant run extraction turbines which produce power for a caustic-chlorine plant on the site. (Caustic soda is a principal raw material in the manufacture of alumina.) An intermediate stream from the alumina plant is used to make aluminum fluoride, used in the reduction process. The chlorine from the caustic-chlorine plant offers several future possibilities for chemicals expansion. Hydrogen fluoride generated for the aluminum fluoride plant is used to produce fluorocarbons.

Effect of mechanical changes.—Table 3 lists a few examples of mechanical changes which have been made in aluminum. The tabulation indicates the way in which process improvements and modifications steadily increase production and reduce costs.

TABLE 3.—*Effect of mechanical changes on operation capacity*

Description of operation	Mechanical changes	Percent capacity increase
1. Aluminum wrought ingot is remelted for alloying and casting into sheet rolling ingot in a typical size of 16 by 44 by 112 inches.	Replaced square remelt furnaces having side loading charging machine with round furnaces having removable tops for crane handled charge bucket loading. Melting and casting can be performed simultaneously.	+15
2. Sheet rolling ingot is scalped by planing the 44 by 112 inches surfaces prior to hot rolling operation.	Mechanized scalping operation to achieve a programed machine controlled operation and eliminated a remote chip haling operation.	+8
3. Hot rolled coil is further reduced in gage by cold rolling operations.	Replaced three to five individual cold mill operations on conventional one or two stand cold mills with a five stand cold mill operation which eliminates coil changes between cold mill stands.	+17
4. Extrusion billet, which is cylindrical in shape, is loaded into the extrusion press container for extruding into various shapes by pushing the heated aluminum through a die.	Automation of the billet loading and butt cut-off and removal reduced the press dead cycle time.	+11
5. Cable stranding from wire.....	Redesign of stranders to handle larger diameter bobbins.	+13

B. Refractory industry

Kaiser Refractories, a division of Kaiser Aluminum & Chemical Corp., is a completely integrated producer of acid and basic group refractories.

One common type of refractory is made from periclase (a dense crystalline form of magnesia) and chrome ore. Large tonnages of this refractory are used for lining open hearth and electrical steelmaking furnaces, the high temperature zones in cement and lime kilns, glass furnace regenerator systems, copper reverberatory furnaces and converters, and a variety of specialized applications.

The principal sources of raw materials for making periclase are natural magnesite (magnesium carbonate), dolomite (calcium magnesium carbonate), sea water and brine. The process starts with dolomite rock which is quarried, crushed, screened, and calcined in rotary kilns to remove carbon dioxide. Calcined dolomite and pretreated sea water are brought together in huge tanks where a reaction takes place forming magnesium hydroxide.

After thickening and filtering, a thick paste of highly pure magnesium hydroxide is fed into rotary kilns along with carefully controlled additives. The resulting product, periclase, is highly refractory and will not appreciably change in size when subjected to further heating. In inland areas, brine from deep wells is utilized for making periclase.

As Moss Landing, Calif., Kaiser Refractories operates a plant to produce magnesia and periclase, materials which are used primarily in the manufacture of basic refractories. The plant digests calcined dolomite with softened sea water in a reactor to produce magnesium hydroxide. After thickening and filtering, the hydroxide is burned, together with certain additives, to produce magnesia, usually in the form of periclase. The spent sea water is returned to the sea.

Since the plant was built in 1942, a number of major additions and improvements have been made. The time and man-hours required to produce a ton of material has shown a steady decline. The table on the following page shows, at 5-year intervals, the relation between man-hours worked and capacity. Also shown, as a measure of the increase of capacity, are the billions of gallons of sea water processed per year.

Year	Tons capacity per year	Man-hours per year	Man-hours per ton of capacity	Gallons of sea water processed per year
1949-----	31,200	164,000	5.25	2,309,000,000
1954-----	79,780	170,000	2.13	5,904,000,000
1959-----	126,580	186,000	1.47	9,367,000,000

When the plant was built in 1942, it had one rotary kiln. The capacity was more than doubled when a second and larger rotary kiln was added in 1950. With the increased capacity in 1954, only a few additional man-hours were required. In 1957, another major change was completed with the addition of a third kiln and other major improvements and expansion in the reaction and thickening systems.

C. Cement and gypsum

The principal production operations carried out by Kaiser Cement & Gypsum Corp. include the manufacture of portland and special cements, plaster, gypsum wallboard, lath, and sheathing.

Cement.—Cement production facilities are located in the States of Washington, California, and Hawaii and have a combined capacity of over 7 billion pounds per year of cement. Limestone, clay, and raw gypsum are the principal raw materials used in cement production. The limestone, a form of calcium carbonate, is quarried, crushed, and ground in a series of grinding operations. After a screening process, the pulverized limestone is pumped in a water suspension to blend tanks, where clay, iron ore, and other elements are added. The agitated "slurry" is fed into revolving kilns which burn the slurry mixture at 2,700° F. producing white-hot clinkers. The clinkers are cooled and pulverized in ball grinding mills. Raw gypsum is added, in varying amounts, prior to the grinding operation to control the setting time of the cement.

The initial plant, built in 1939, employed the largest equipment known to the industry at that time.

The company's second plant, built at Cushenbury in California's Lucerne Valley in 1957, was outfitted with 1,500-hp. mills, the largest grinding mills then available. During the 1962-63 expansion the plant was equipped with the West's largest kiln, 16 feet diameter by 520 feet long, and the biggest cement grinding mill in the world, 4,500 hp. These giant facilities doubled the plant's capacity with no increase in work force and with striking capital cost benefits. At the same time the larger kilns required 7 percent less fuel per unit of production.

Gypsum.—Gypsum plaster and wallboard are made in several locations of Kaiser Gypsum Co., Inc. Raw gypsum ore is the principal raw material for the production of plasters, gypsum wallboard, lath, and sheathing. The ore, a chalk-like rock of calcium sulphate dihydrate, is quarried, crushed, and ground to a fine powder. The powder is calcined at a temperature of 250° to 350° F. which drives out approximately 75 percent of the chemically combined water. The resulting calcium sulphate hemihydrate is reduced to microscopic flakes in a rotating tube mill, partially filled with steel balls. This improves the "stucco's" plasticity, aging properties, and workability when used as plaster.

After ball milling, the "stucco" is combined with retarder and other dry ingredients to produce plaster, which is sacked by high-speed machines.

For gypsum board products the "stucco" is mixed with paper pulp, foam (to decrease the product density), starch, and water to form a thick slurry. The slurry is discharged onto an unreeling roll of manila paper. Over this goes "grey back" paper to form a sandwich. The continuous gypsum board sandwich moves on belts and rollers along huge "board making" machines. The long sandwich is cut into lengths at the end of the board-line and dried.

Each of the four existing gypsum products plants is designed for efficient, straight-line production. The plants have been continually modernized, resulting in increased instrumentation and centralized process control. The new Jacksonville plant incorporates the latest steps toward automation.

Specific examples of process improvements in Kaiser Gypsum plants are shown in table 4.

TABLE 4.—*Specific examples of process improvements, Kaiser Gypsum Co., Inc., 1960-64*

	<i>Effect on process (reductions in cost of 1,000 square feet of wallboard)</i>
Process improvements:	
1. A method was found for substituting a waste material for a purchased raw material-----	\$0.20
2. An improvement was made in the method of winding and handling paper rolls-----	0.07
3. A dry weight reduction was made possible by improved additions and product control-----	0.12
4. A kettle was automated resulting in increased production-----	0.03
5. An improvement was made in the handling of pulp used in the gypsum board core-----	0.20
6. The first zone of the dryers was changed from steam heated to direct gas fired, permitting faster drying-----	1.30
7. An improvement in instrumentation to produce more uniform thickness-----	0.03

D. Steel industry

Kaiser Steel Corp. is a fully integrated producer of rolled and fabricated steel; i.e., it mines the ore and coal, and smelts the ore into pig iron and makes and processes steel for sale. The company's steel mill at Fontana, Calif., has been under almost continuous expansion since its initial facilities were built in 1942.

The basic raw materials used in steel production—iron ore, coal, and limestone—are supplied from the company's western mines and quarries. The ore, which averages 42 percent iron as mined, is upgraded (beneficiated) to 60 percent before shipment. The coal is processed into coke in coke ovens.

The beneficiated iron ore, coke, and limestone are fed into the top of the blast furnaces by skip cars. The furnaces smelt the raw materials and reduce them to molten pig iron and slag. At intervals the iron is tapped from the pool of hot metal formed in the hearth of the furnace and is transferred by a "torpedo" car to the steelmaking furnaces.

The molten pig iron is then fed into steelmaking furnaces along with steel scrap and other materials, under close quality control, and converted into steel. These steelmaking furnaces are of two types, those using the open hearth method and those using the L-D processes, a basic oxygen steelmaking technique. After the steel is tapped, it is poured into molds to form ingots from which, after a brief cooling period, the molds are stripped and the ingots placed in soaking pits until moved to the rolling mills.

The first step in rolling takes place in either a slabbing or a blooming mill where the large preheated ingots are rolled into smaller and more easily handled shapes called slabs or blooms. From this "primary" rolling stage, the steel is distributed among the Fontana plant's nine other rolling mills for finishing to final shape; e.g., sheet, pipe, structural bars, tinplate.

High grade iron ore for Fontana's blast furnaces comes from the company's mine at Eagle Mountain, Calif. The ore is mined in huge open pit operations in which overlying rock is stripped to expose the ore. The beneficiation plant upgrades the ore by separating waste materials and low grade ores from the higher grades to increase the iron content. The production and iron content of the ore shipped from the beneficiation plant has been upgraded by a series of process additions and improvements. In 1953, the annual beneficiated ore production was 1.8 million tons with an iron content of 55 percent. In 1954, heavy media and dry magnetic separation was added for more beneficiation; in 1955, a jig plant; and in the 1961-63 period, a wet magnetic separation process was added and further crushing, blending, and mining improvements were effected. Each of these process improvements has resulted in a higher grade ore for input to the Fontana blast furnaces. In 1964, production increased to 5.2 million tons per year with a 60-percent iron content. At the present time, a new pelletizing plant is under construction. The pelletizing plant will be equipped with the world's largest pelletizing machine. Though a basic magnetite, the concentrate contains 20 to 50 percent hematite, necessitating a flexible process to yield consistently good pellets from a varying concentrate. Pellet drying, firing, and cooling will all be carried out in one piece of equipment.

The potential pig iron production from the four Fontana blast furnaces has increased during the last 7 years from a total of 5,800 net tons per day in 1957 to 6,950 net tons per day in 1964 (a 20-percent increase). Again, a key factor in this production increase has been the improvements effected in iron ore beneficiation. This has resulted in a higher iron content in the ore fed to the blast furnaces, less gangue (or mineral contaminants), and better burdening of the ore. Due to the reduced gangue content in the ore, the volume of slag has been correspondingly reduced. Another process improvement, which has resulted in increased potential production, has been the replacement of refractory brick linings with carbon linings. This has increased the effective volume of the blast furnaces.

The older method of steelmaking is by the open hearth process. The open hearths are low, rectangular, stationary brick structures with a furnace interior shaped like a shallow dish. Limestone, steel scrap, and molten pig iron are charged through water-cooled doors in the front. The production capabilities of the Fontana furnaces have been considerably enhanced by oxygen enrichment. The first improvement was the use of oxygen in the end wall burners. This increased the average capacity from 21.9 ingot tons per hour to 28.5 ingot tons per hour, an increase of 30 percent. The most recent innovation has been the use of an oxygen lance through the furnace roof. This has further boosted the average production to 36.1 ingot tons per hour, another increase of 26 percent.

TABLE 5.—*Specific examples of process improvements, Kaiser Steel Corp., Fontana, Calif., period 1957-64*

Item	Improvements	Effect of process change
Blast furnaces:		
Coke rate.....	Improved ore quality.....	} 24 percent reduction.
	Natural gas injection.....	
	Self-fluxing sinter.....	
	Increased air temperature.....	
Hot metal potential production....	Improved ore quality.....	} 20-percent increase.
	Carbon linings.....	
Open hearth steelmaking furnace:	Oxygen in end burners.....	} 30-percent increase.
Average daily production.	Oxygen lance through roof.....	
		} 26-percent increase.

SECTION III. ENERGY CONSUMPTION TRENDS

The electrical utility industry in the United States is a clear example of reductions of the cost of a utility service resulting from technological improvements. Part of the reductions in electric power cost have been improvements in the powerplant cycles due to higher temperatures and pressures, made possible by advances in metallurgy and process design. Larger size units have also been important in reducing unit costs and these again have required stronger steels for turbine rotors, new turbine blade designs and improved boilers. The resulting improvements in efficiency are reflected in the remarkable reduction of pounds of coal used per kilowatt-hour generated and are shown in table 6.

TABLE 6.—*Fossil fueled powerplants*

Year	Pounds of coal per kilowatt-hour
1925.....	2. 029
1930.....	1. 596
1935.....	1. 439
1940.....	1. 340
1945.....	1. 302
1950.....	1. 189
1955.....	0. 954
1956.....	0. 935
1957.....	0. 928
1958.....	0. 904
1959.....	0. 890
1960.....	0. 876
1961.....	0. 863
1962.....	0. 858
1963.....	0. 856

The cement industry and steel industry have made similar improvements in energy consumption. The improvements in efficiency in the cement industry are primarily due to increases in kiln size and grinding mill size. The 16-foot-diameter by 520-foot-long kilns require 900 cubic feet of natural gas per barrel of cement produced, whereas the 12-foot-diameter by 450-foot-long kilns being built in 1957-58 required 1,200 cubic feet of natural gas per barrel produced.

The cement industry has also reduced unit electrical energy consumption by increasing the grinding mills from 9.6 feet diameter to about 15 feet diameter. Milling efficiency increases with increasing diameter. A 20-percent energy reduction has resulted from this change.

In the steel industry one of the most important cost factors in blast furnace operations is the coke rate (pounds of coke consumed per ton of iron smelted). At Fontana the coke rate has been reduced from 1,490 pounds per ton in 1957 to 1,130 pounds per ton in 1960, a 24-percent reduction within a 7-year period. This has been accomplished through several process improvements.

(a) Beneficiation improvements in ore quality.

(b) The use of self-fluxing sinter.

(c) Natural gas injection.

(d) Increasing the temperature of the air supplied to the blast furnace.

A portion of these energy gains in the electric utility, cement and steel industries has been accomplished by going to larger sizes. But the increase in efficiency is only a part of the gains in scale-up. Gains in capital cost per unit of production may be expected. Section IV describes the effect of scale-up.

SECTION IV. SCALE-UP IN COMPONENT AND PLANT SIZE

The reduction in capital cost per unit of production is a commonly expected benefit from increased size.

The electric power industry has made great cost reductions by going to larger unit capacity in the fossil fuel installations and is now making greater gains in the nuclear power field. These scale-up unit cost factors are shown in table 7. Also shown in this table are the busbar energy cost for the nuclear plants: a true measure of overall cost of producing power.

TABLE 7

Megawatts capacity	Station fossil fueled, ¹ capital cost, dollars per kilowatt	Station, nuclear fueled, ² capital cost, dollars per kilowatt	Cost of power, mills per kilowatt-hour
60	195	1,222 (Shippingport)----- 325 (Pathfinder)-----	60.15
75	188	-----	-----
100	172	-----	-----
150	155	-----	-----
175	-----	224 (Yankee)-----	11.0
200	-----	183 (Dresden No. 1)-----	9.0
300	140	-----	-----
500	130	180 (9 Mile Point)----- 132 (Oyster Creek)-----	6.67 4.25
1,000	128	-----	-----

¹ Electric World, Oct. 7, 1963, "12th Annual Steam Station Cost Survey."

² Electric World, May 1964, "9th Annual Nuclear Power Report."

The cement industry is benefiting from scale-up factors both in component size and in overall plant capacity. The grinding mill cost per unit of capacity is shown in table 8. The scale-up of grinding mills, it should be pointed out, is the result of extensive development. In fact the scale-up of modules, components, and whole plants in most industries requires a developmental program to determine how to design the larger equipment.

The cost trend of scaled-up cement plants as a whole follows the trend of the grinding mills as shown in the companion table.

TABLE 8

Cement plant capacity (million barrels per year)	Ratio, grinding mill cost per unit of capacity	Ratio, plant cost per unit of capacity
1.....	100	100
2.....		84
3.....		74
4.....		68
5.....		
6.....	68	
7.....		
8.....		60
9.....	60	60

The scale-up effects in the iron ore mining area include increasing the capacity of shovels and trucks. Kaiser's Eagle Mountain mine uses a variety of capacities and the operating costs per unit of capacity show the scale-up advantages.

Ratios, operating cost per unit of capacity

Truck capacity:	<i>Tons</i>
40 to 65.....	100
100.....	60
Shovel capacity:	<i>Cubic yards</i>
4.5 to 5.....	100
8.....	60
12.....	50

CONCLUSIONS

In summary I have tried to show four areas of cost improvements in the process industry:

(a) The trends of lower man-hours per thousand pounds of product—a trend downward in four basic industries.

(b) A series of stepwise process improvements, some resulting in large cost savings, and nearly all associated with increasing the capacity of a plant component or module. Increased temperature, higher flows, better control of chemical treatment and more efficient equipment were all significant in these gains.

(c) The trends in reductions of energy consumption, more product per pound of fuel, and use of larger and more efficient equipment (ranging from ball grinders to shovels and trucks to kilns and turbines).

(d) The unit capital cost reductions associated with scale-up, and the developments which are necessary to be able to scale up the designs.

These four areas are interrelated and complex. Increased efficiency will lower energy costs and capital costs may reduce manpower and may make a previously uneconomical process competitive.

An example of the above interrelation is dramatically shown by the dual purpose Volta River Hydroelectric-Volta Aluminium Co., Ltd., project in Ghana, West Africa. Modern engineering and construction technology have made the Volta River Dam feasible. This 10-million-cubic-yard rock-fill dam, 370 feet high, and with a 2,100-foot crest length and associated hydroplant will cost about \$180 million and produce 768 megawatts of power. A 67-mile-long, 161-kilovolt transmission line will supply this power to local industries and for aluminum manufacturing.

The availability of low-cost power and African aluminum-bearing ores are responsible for the feasibility of the aluminum reduction plant now being built. The reduction plant will cost about \$128 million and has a first-stage annual capacity of 100,000 tons of aluminum.

The availability of low-cost power and aluminum may trigger still more interactions of industrial processes.

What are the cost reduction chances for the desalting process? The proper answer is not a guess but a projection of the history of basic industries: Process improvements, developing ways to increase capacities of modules and components, reducing energy consumption, and increasing module size. These have resulted

in the past from higher temperature operations, lower cost power, larger equipment, and improved process control. Also, process improvements have come about from new steel furnace and blast furnace liners, larger trucks and materials handling equipment, larger and more efficient grinding mills, and finding substitute lower cost materials to accomplish the same purpose.

The desalting counterparts may be better scale control, higher brine heater temperature, lower cost waste heat from nuclear dual-purpose plants, higher capacity modules and new feed water treatment methods. We can also expect lower unit costs with plastic coatings for concrete or new concrete formulations, larger and more efficient pumps and perfection of the use of sea salts in "seeding" for scale control or for new industrial or agricultural uses.

Development of many of these improvements will take time and their interrelation in the process complex, but until demonstration plants first and then increasingly large plants are built and operated, the true effects will not be realized. One thing is certain—with the advent of these plants, the reductions in the cost of desalted water will follow the same dramatic and inexorable path still being experienced in other and older basic industries.

Mr. Chairman, I thank you for your attention and this opportunity to appear before you and members of the committee.

Biographical Sketch of Philip D. Bush

Vice president in charge of Advanced Technology Projects Division, Kaiser Engineers, Oakland, Calif.

Born 1917, attended Stanford University. BS degree in electrochemical engineering and master of science degree in metallurgical engineering at Massachusetts Institute of Technology, 1939. Graduate studies in nuclear physics and nuclear engineering at the University of California.

Early experience in metallurgy and operation of steel mills and byproduct coke plants. Subsequently in charge of work involving design and operation of cement plants, gypsum plants, aluminum and metal products plants; engineer in charge of air pollution control engineering for steel mills, aluminum and cement plants; Manager of Nuclear Projects Department. Currently responsible for management of Kaiser Engineers' nuclear engineering, powerplant, space, defense, and desalination projects.

Acted as project manager for the design and construction inspection of the following:

- Engineering test reactor for the U.S. Atomic Energy Commission at Idaho Falls, Idaho

- Experimental gas-cooled nuclear power reactor for the U.S. Atomic Energy Commission at Oak Ridge, Tenn.

As division manager, responsible for the following:

- The safety test engineering program power reactor facility for the U.S. Atomic Energy Commission in Idaho.

- The experimental beryllium oxide reactor for the U.S. Atomic Energy Commission at Idaho Falls.

- Large seed and blanket nuclear powerplant (State of California); preliminary design.

- U.S. Navy nuclear power studies for multiple utilities.

- U.S. AEC's reactor cost handbook.

- Arizona Electric Power Co. combined cycle powerplant design and construction inspection.

- United States-Israel dual-purpose power-desalted water plant feasibility study.

- NASA-Plumbrook Space Propulsion Facility design.

- NASA-Houston, integrated mission control design (Gemini/Apollo).

- NASA-Houston Space Environment Laboratory upgrading design.

- U.S. Air Force Vandenberg advanced launch complex design.

Member of the American Nuclear Society, the Nuclear Engineering Division of the American Institute of Chemical Engineers, and the American Institute of Aeronautics & Astronautics. Member Tau Beta Pi and Sigma Xi honorary engineering and scientific fraternities.

Mr. BUSH. One hears that nuclear power has, with the aid of significant Government research and significant industrial research, come of age, and that the costs have been reduced substantially and that after these billions have been spent, we have arrived at a plateau and hope for a higher plateau.

We have also heard that the cost of desalting water has dropped from \$6 a thousand gallons to less than \$1 a thousand gallons. So one might have the next thought process that if we were to spend enough money, both Government and industry, that the cost of water should come down substantially further. I happen to be one who subscribes to just that. But in answering the doubters I have prepared our own records of experience on what has happened in the more basic, prosaic U.S. industry and those industries that one might have considered even mature in the middle 1940's, or even the middle 1920's. I refer to steel, aluminum, cement, gypsum, power, and so forth.

For instance, on a plant designed in 1942 in the aluminum industry the average through the cell, which is the relation one makes for production, was only 32,000 amperes. The plants we are designing right now are 150 amps, with the increased specific production.

In 1949, the aluminum industry as a whole required 14 man-hours per thousand produce pounds, and today it is less than half of that.

In the cement industry the plant we designed in 1958, modern, required a half a man-hour per thousand pounds of product, and the plant we designed last year to come on the line next year will require only three-tenths of a man.

How is this accomplished? For instance, the grinding mills in that cement plant used to have 1,500 hours power motors and that was as big as industry could build for us for this particular service. The most recent plant is 6,000 hours power.

The kilns were 12 feet in diameter and around 400 feet long. Now, the kilns are 16 feet in diameter and more than 500 feet long. It wasn't a question of building a bigger shell and putting brick in there, it was a question of getting proper brick and proper binders, and this required pilot plant work in order to accomplish this, not research laboratory work, alone.

In our magnesium plant off the coast of California, or on the coast of California, where we process now 9 billion gallons of sea water per year, and where just a few short years ago we processed only 2 billion gallons of sea water a year, we only require one and a half man-hours per thousand pounds of product as compared with, I think, 15 years ago, around 5 man-hours per thousand pounds of product.

The power industry, of course you are all familiar with, where in the middle 1920's it required 2 pounds of coal to make a kilowatt-hour. The most recent plants are down under seven-tenths of a pound of coal per kilowatt-hour, and the accomplishments in the power industry are, of course, well known to all of you. These were mature industries, and yet, the improvements in process from scale-up in size and technological improvements have meant continued reductions in cost, and I am sure you will agree that in the process of desalting water that we haven't even begun to mature.

The trend is down. But the indication here is that the trend has been, in some people's opinion—in mine, too—slow. It comes because private industry cannot—and maintain its reasonable profit struc-

ture—pour millions and millions and millions all at once into programs. They do it slowly. If we could afford the normal pace of industrial research and development and technological development, we could very well go right along now, without the support of the OST. However, because of the need for relative speed, I think the program requires continued team effort of Government and industry.

Cases that are similar are atomic energy, electronics—I refer most recently to NASA's new electronic research lab going up in Cambridge—and in the conquest of space. But I then ask you, what is more vital than water, the one single thing you cannot do without?

There are those in our business who say, "Leave it to us right now. We will build you, say, a 50-million-gallon-per-day plant and just go away and it will run." But the cost of water may be, 20, 40, 50, 60 cents per thousand gallons and one must look very closely at the basis for those cost figures, particularly with respect to plant life, fixed charges, and the like.

Even if one supported this, there are only one or two at this point who are doing it. This does not mean to take away the very fine work that these companies that are saying this have done. They have done very good work. But at the same time we need to continue the development which will really take the cost down by another factor of 3, or 4, and it is today's development and research work and pilot plant, module, component work over the next few years, which is going to bring us—if it is humanly possible—to the point where we do have water at substantially less than 30 or 35 cents per thousand gallons.

I can remember in my own experience just 10 years ago listening to the nuclear energy advocates say that they were going to make, within just a year or two, 7 mill power. That was the fashionable number of the day, because that was the competitive cost fairly widespread throughout the United States on fossil fuel fired power at the time. So everybody made his calculations, based upon 7 mill power.

Well, it will be 1968 before we have it. But the interesting thing is that the companies who were keeping quiet about 7 mill power at the time, and going about their work are the ones now—the General Electrics and the Westinghouses and so forth, who are beating that 7 mill power, and doing it in the neighborhood of 4 mill power.

But my point here is that it did take some time to do it, but that the combination of private industry and Government, each supporting the other, did wind up with not only meeting 7 mill power but getting down into 4 mill power, and this is the complement to be offered.

Really, the thing that I think you must understand is that the one side of the fence, the process that is most thoroughly developed now: multistage flash evaporation, is ready for large module, large component pilot plant, and within 5 years large plant construction, but there are these other processes of the membranes and freezing which require the development work today, and we are not sure which one of these, if any of them, is going to prevail.

The technological breakthrough answer is something that we have to strive for, also, on something that isn't even up for consideration, today.

Now, it is axiomatic that when natural resources begin to be depleted that the cost of any incremental use thereof is going to be more expensive than anything we have had before. Whether it is fuel or copper, or iron ore. Unless we are able to import it or find substitutes,

Let's look at importing water for a minute. We have some very far-reaching schemes being presented these days for the importation of Canadian and Alaskan water. Nobody is really talking about the cost of that water yet, as to what it is going to mean to get it down even as far as Mexico. But the schemes are being studied and it is good that they are. No one knows whether those schemes will be competitive with desalted water on an equal basis of continued research and development for us.

The other thing, too, is that we must continue to press on both fronts. Water is something that with our expanding population there is no turning back on. Every time you turn around and try to find an alternate one still comes back to the same problem of the expanding population. It doesn't matter whose numbers are being projected and whose are right, the number is going to expand and rapidly.

It isn't only in the West where we have the combination of rapidly expanding population and shortages of water. Who would have guessed that Long Island would be interested in a desalting plant? And if they are short of water now, what is going to be 10, 15, or 20 years from now with the continued expanding of our population, and one should not be concerned with which place is expanding more rapidly. Every place is expanding.

So in conclusion I would like to think that those charged with the responsibility for this program do consider that it is a nationwide program, not a regional program, and that industry is prepared to work with the Government, each one pursuing the objectives—and I think what Mr. Di Luzio said yesterday about where the Government stops and where industry takes responsibility is what all of my counterparts in industry believe to be the proper role.

Thank you.

Mr. ROGERS. Mr. Bush, do you feel that we have reached the point in the multistage flash installation of research to develop the field to the point it would be practical and advisable at this time to move on into the production stage, 40-, 50-, 60-million-gallons-a-day plants?

Mr. BUSH. I think what we are all saying is that we must plan for its construction, whether it is 3, 4, 5 years from now. I don't think anybody would quibble.

Mr. ROGERS. Have we reached the point in the development so far in working out these different phases of this multistage flash process to the point that to spend additional money on additional demonstration plants would not promote the best interests; that our interest could best be served by moving on into the production?

Mr. BUSH. There are certain phases of multistage flash process where development is still needed in corrosion, in some of the large pumps, and this is what we are looking for in these, either modules or large component development work.

I would think, and I am probably not the most qualified in the room, but I will go out on a limb on this, that the basic research connected with multistage flash evaporation has reached maturity.

Mr. ASPINALL. Mr. Bush, a chart on page 3 of your statement shows reductions in the price of aluminum over a 60-year period, through 1945. What is the present price?

Mr. BUSH. The present price, and I think the comparable one on ingot, is around 26 cents.

Mr. ASPINALL. How much does an ingot weigh?

Mr. BUSH. An ingot is almost any size you choose. This is per pound, if this was your question, sir.

Mr. ASPINALL. You have the 1945 price per pound at 14 cents. That is what is bothering me.

Mr. BUSH. Since 1945 the cost of materials and labor have been up significantly. The issue here is that as plants have increased in efficiency and size and the amperage, for instance, for the cell has gone up, the man-hours per pound have gone down, which is the real criteria for knowing whether you are improving. Those are things over which you have control. The cost of labor and actual materials is a rather difficult thing these days.

Mr. ROGERS. You mean the price of man-hours has gone up?

Mr. BUSH. That is correct.

Mr. ASPINALL. Kaiser hasn't been one of those backward companies in recognizing this; is that right?

Mr. BUSH. That is correct.

Mr. ASPINALL. What comparable stage of cost reduction has been reached in the art of desalting? As you go through your tables, here, do you have any place to tell us whether we are 1885 to 1910, or—

Mr. BUSH. I would agree with your 1910.

Mr. ASPINALL. How much has Kaiser Industries spent on research into the desalting techniques?

Mr. BUSH. Kaiser Engineers as a company is not concerned with research, sir. We are engineers, designers of plants, and constructors of plants; not manufacturers.

Mr. ASPINALL. What did you receive for that purpose?

Mr. BUSH. We received nothing. Our contract has just been signed.

Mr. ASPINALL. You have received no money up to the present time, then, from the Office of Saline Water?

Mr. BUSH. That is correct.

Mr. ASPINALL. You used your illustrations as to the development in the various fields in which your company has been interested simply as an illustration of what may happen as far as the production of potable water from brackish or sea water is concerned; is that right?

Mr. BUSH. It is based on my knowledge and faith in U.S. industry as to what can be done—the point I wanted to emphasize was that most of these cost reductions I have cited were in industries that were already mature, so that the horizon is unlimited in desalting.

Mr. ASPINALL. How big is the contract that you presently have a request for before the Office of Saline Water?

Mr. BUSH. Sir, we have already been awarded the contract. That is for a \$341,000 amount.

Mr. ROGERS. Mr. Hosmer.

Mr. HOSMER. As I understand, Kaiser Engineers of Oakland, Calif., are ready, willing, and able, under the contract, to go to work; is that correct?

Mr. BUSH. I am sorry. I am missing your point, sir.

Mr. HOSMER. You haven't done any of this work so far, but now your company is ready, willing, and able to go to work in the field?

Mr. BUSH. We have already begun working.

Mr. HOSMER. We understand that you are a capable firm.

Mr. BUSH. Yes, sir. We hope you understand that.

Mr. HOSMER. I rather assume that the purpose of this "auction block" this afternoon is to get everybody's credentials on the record, and I want to make sure.

Thank you.

Mr. ROGERS. Mr. Reinecke.

Mr. REINECKE. When you refer to the improvement and refinement, is there some doubt in your mind?

Mr. BUSH. Do I understand your question—

Mr. REINECKE. Yet me rephrase it.

Mr. BUSH. All right.

Mr. REINECKE. You made the statement that by engineering refinements and improving components, modules, et cetera, we would bring the price down to a realistic figure if it was humanly possible? Is there a question in your mind as to whether we can?

Mr. BUSH. There is no question in my mind, no, about bringing the price down to what I consider to be a reasonable figure. I could say that that number is 32 cents.

Someone else in good conscience may have a figure of 15 cents. What my point is is that this next stage of plant must test out the component for long life—and I must say the plant must last 30 years. So the plant must have components for that and must be tested. Corrosion must be tested. New materials. The plastic link of large concrete shells, in order to get away from saline corrosion. These are things that must be tested out in a demonstration plant.

Mr. ROGERS. Thank you very much, Mr. Bush, for your statement and your answers.

Our next witness is Mr. Russell L. Haden, Jr., president of Ionics. Mr. Haden.

STATEMENT OF RUSSELL L. HADEN, PRESIDENT, IONICS

Mr. HADEN. Representative Rogers, Mr. Aspinall, members of the committee and guests, my name is Russell L. Haden, and I am the president of Ionics, Inc., located in Cambridge, Mass. Ionics is the pioneer company in the field of electrodialysis which is a process for removing dissolved salts and minerals from saline waters by the use of electrical energy and special plastic membranes. Electrodialysis was first demonstrated on a practical basis in the early 1950's and today is in commercial use throughout the world in more than 125 plants supplying fresh-water needs to cities, industry, and military installations. The Office of Saline Water has assisted in the development of this process over the last 10 years.

Your notice of hearing, Representative Aspinall, stated that your committee desires testimony from many sources on the proposed expansion of the OSW program and particularly on where the Federal Government's responsibility ends and that of private industry begins with such a research program. Recognizing the importance of fresh water to mankind, all of us hope for a breakthrough which will significantly lower the costs of saline water conversion so that it will be universally useful, as President Johnson said, both to "meet our ever-growing domestic needs for water and, at the same time, provide the technology that can be shared with other nations." As enticing as this prospect is, we believe it is the consensus of

experts in the field that a true breakthrough is unlikely and that a well-planned program of hard work and thorough investigation to build on current technology is what is needed to further progress in these directions.

Our understanding of the program to be supported by H.R. 7092 is taken from the report to the President dated September 22, 1964, entitled "Program for Advancing Desalting Technology" (which I will abbreviate as the Holum report). On page 7 of this report there is a chart which shows that expenditures beginning in 1966 would be 41 percent on distillation and 14 percent on reverse osmosis. No other single process comes even close to these spending levels.

Distillation is an ancient process, used commercially on ships over 100 years ago. Its application now, on land, is for sea water conversion and so, primarily for coastal communities. It is also aimed only at large plants in order to reach reasonable costs. In very large plants, such costs were predicted in the Office of Science and Technology Report titled "Large Nuclear Powered Sea Water Distillation Plants," to be in the range of 30-40 cents per thousand gallons. Plants of this size would produce 300-1,000 million gallons per day, equivalent to the entire domestic water needs of 2-7 million people.

Fourteen percent of the program is to be on reverse osmosis. Reverse osmosis is the newest of processes, and in the very early stages of development. There are still real engineering questions as to whether it can be scaled up from its current pure research size and there operate at reasonable costs. Secondly, if it can be scaled up, this process is still at least 10 years away from normal commercial application as judged by past experience with development time schedules.

Despite the expected Federal expenditures in both the oldest and newest processes, private industry is ready to risk its own personal capital. For example, the Westinghouse annual report stated that that company is prepared to build and guarantee a 50 million gallon per day distillation plant on sea water. We believe the cost will be under 40 cents per thousand gallons. If so, private industry then is already prepared to do even better than the OST predicted a year ago (March 1964).

Since selling our first water plant in 1953, Ionics has invested close to \$1 million by incurring losses which we expected would arise in gaining knowledge the hard way. To include people to buy, we have quoted low prices and have guaranteed performance. We have thus invested private capital to gain this knowledge because we have faith in eventual commercial success in the future market for saline water conversion.

I mention the above examples because I have some suggestions to offer on the Federal program:

First, we have made two proposals on research to the OSW which we are told have real technical promise. In these, we proposed to put our know-how on membranes to work to improve reverse electro-dialysis and osmosis. However, we recently have been told that for us to participate, we will have essentially to give up control of our background patents. This we cannot do, and if these restrictions remain, our know-how cannot be used to speed this program.

I think what I propose here would fit Mr. Di Luzio's definition of a first generation plant, and I also think this is consistent with what Mr. Ennis was saying, that private agencies follow where OSW leaves off.

Our feeling seems to jibe with that of Presidential Science Adviser Dr. Donald Hornig, who was quoted in a February 18 letter to the Senate Public Works Committee as saying that a blanket Government-title policy would hamper private investment. We suggest, therefore, that Congress make its intent clear so that Government attorneys will not feel it necessary to interpret the law so narrowly.

Secondly, we believe that the building of an electrodialysis plant in the 5-10 million gallons per day range now could be done at minimum expense and would be a significant contribution to the desalination program. Such a plant would supplement the programs on distillation, offset some of the risks in reverse osmosis, and gainfully use some of the moneys to be committed by passage of this bill.

It would be 10 times the largest plant currently in operation and would produce water at about 20 cents per 1,000 gallons. If a one-shot grant, in principle like the grants now being made available to towns for sewage systems, were offered, it might persuade a community needing water to put in a desalination plant now. Otherwise, cities and towns are tempted to put off their requirements for desalination plants, hoping for the breakthrough, or at least for future lower costs from the Federal research program.

A plant of this 5-10 million gallons per day size, though large for electrodialysis, would still be quite small compared to the 50-150 million gallons per day prototype distillation plant now being studied for southern California. Scale-up of electrodialysis by the factor of 10 would have the effect of cutting the costs of the water produced in half. Figure 1 in back of this report illustrates this point. The costs shown on this graph are realistic and based on today's technology. We would stand back of them if such a plant were to be built right now. You will notice that the cost of the water produced would drop from about 40 cents per thousand gallons (to the left, on the middle curve, at 0.65 million gallons: Buckeye size) to about 20 cents per thousand gallons (at 10 million gallons per day).

If you will refer to the chart at the rear of my report, you will see it begins at a million gallons per day and therefore, to put Buckeye on this curve you would have to go to the left of the left-hand axis and because brackish water does not have a single salinity, as sea water is assumed to have, we have 3 curves of 900, 7,300 per million of salts. Buckeye would be slightly above the middle of those three curves. If you extrapolate that to the left-hand side at 0.65, which is the 650,000 gallons per day, you would find Buckeye would be in a range of roughly 40-45 cents a thousand gallons and if you will now look at the chart itself in the middle curve at a 10-million-gallon-a-day plant we would be at 20 cents a thousand gallons. That is the derivation of my figures.

Mr. HOSMER. These numbers at the bottom, 100-200, what are they?

Mr. HADEN. Those are millions of gallons per day.

Mr. HOSMER. And you go out to 200 million gallons?

MR. HADEN. Yes, sir.

Now, those figures we are referring to there are realistic and are based on today's technology.

MR. HOSMER. What kind of energy cost are they based upon?

MR. HADEN. They are based upon a sliding scale, because if you are buying a few thousand kilowatts you would pay one price; if you are buying tens of thousands you would pay a lot less.

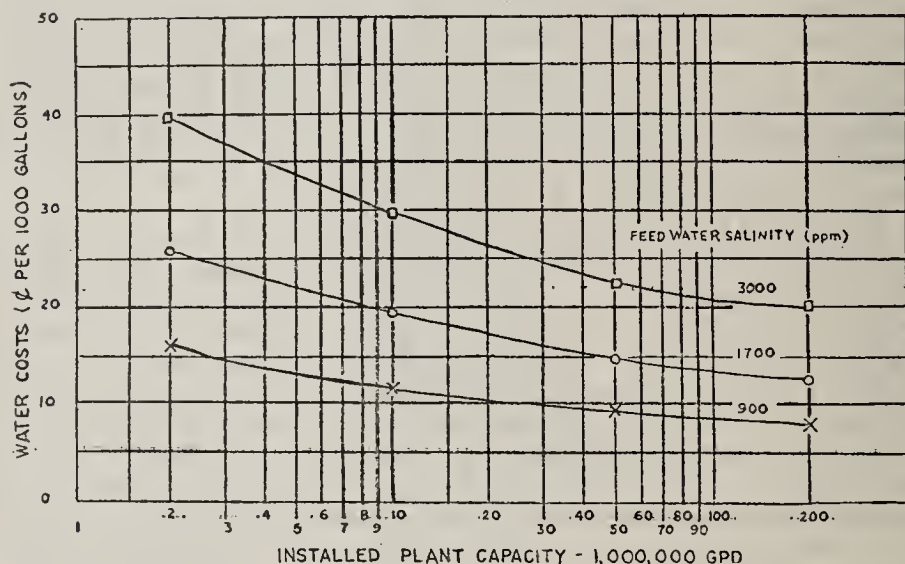
MR. HOSMER. If you buy it from Bureau of Reclamation you will pay one price, and if you buy it from a private company, you will pay another price.

MR. HADEN. On this chart it starts on the left-hand side at 1 cent, or 10 mills per kilowatt-hour and goes out to 6 mills.

We stand back of such a cost if such a plant were to be built right now.

(The table referred to follows:)

ELECTRODIALYSIS OF BRACKISH WATER
TOTAL WATER COSTS IN ¢ PER 1000 GALLONS



MR. HADEN. 20 cents per thousand gallons is a very attractive figure compared to distillation, which would cost 60 to 70 cents per thousand gallons in an equivalent size plant. We are comparing electrodialysis on brackish waters with distillation on sea water, but the product is the same—potable water—in both cases.

One electrodialysis plant built now of this size will produce these benefits:

(a) We would expect that practice would result in significant reduction in operating and maintenance costs below those used in preparing the costs in figure 1.

Here, again, I think this is consistent with what has been said today by other witnesses. It is also consistent with what happened in Buckeye. When the plant was installed there the costs were reduced by them below the cost we predicted by reason of the fact that they had the motivation once the plant was in and was operating to find the most effective way to use their labor and to keep the plant operating.

(b) An order of this size would provide the incentive for private industry to enlarge membrane production facilities and lower membrane costs. These new, lower costs would not only benefit the plants already in use, such as at Buckeye, and the single larger plant proposed, but also all of the future small plants that will be needed in our inland communities. Dr. Eliassen mentions that there are over 1,000 towns using brackish water that could benefit substantially if economical, small size, desalting plants were available.

(c) A plant of this size would provide incentive to power companies to make daily offpeak electricity available at lower rates. The value of a steady bus-bar load and the ease of shutdown and startup of the electrodialysis plant would be demonstrated.

Let me return to that point of over 1,000 small towns. Electrodialysis has the great virtue of being a simple process with high operating reliability. It is good for small towns in that the conscientious personnel available in small towns can do the job easily as shown in Buckeye. There, the operator spends a good bit of his day with other duties, such as repairing cars and trucks. Constant attention to the plant is not needed and no attention is provided during the two night shifts. Since it does not involve complicated, high pressure equipment, but electricity, the local utility can be called on for help when needed.

Also, we feel work should be stimulated on the only sure long-range source of water for most communities which is water that is reused. Water once used by a community has its mineral content increased by 300 to 400 parts per million. Normal water treatment plants remove suspended and organic matter, but not the minerals.

Mild salinity of this order of magnitude is ideal for economic processing by membrane process including electrodialysis.

In summary, we suggest that private industry can play a greater role in the Federal program, if patent clauses are not interpreted restrictively and if grants are made judiciously to stimulate towns to purchase desalting plants now. We would welcome the opportunity to continue to contribute our technology to OSW and other Government programs. We would also welcome financial assistance for a 5 to 10 million gallons per day electrodialysis plant to bring such a plant within the economic ability of a community needing water today. Such a plant would:

(a) Lower costs for both medium size and small plants.

(b) Demonstrate these lower costs and so accelerate planning for and use of desalting technology by inland towns and in smaller plants.

(c) The Holum report quoted a United Nations report as saying:

The water supply requirements of most of the international locations with potential for desalting would be satisfied by small plants.

This electrodialysis technology would also thus be useful to other nations.

(d) This plant would require minimum expenditure by the Government and would simultaneously establish a continuing use.

Speaking of continuing use, I would like to comment, if I could, on Port Mansfield. There was discussion yesterday on Port Mansfield and I would like to add what I know about that.

The Port Mansfield grant was awarded and set up on the basis of plants which used a pipeline, in these cases, not a desalting plant. The

pipeline turned out to be too expensive. Then they turned to distillation. Mr. Di Luzio said yesterday that OSW, itself, was consulted, but he implied there was not much time given for them to consider it. We weren't given much time either. This is something that had to be done to get proper water for this city.

The important thing was that electrodialysis met the test of the market, which Mr. Di Luzio said must be the final judgment.

Let me point out also that I think Port Mansfield would be glad to supply data on the operation of that plant to OSW. On our part, we would recommend they do so in order to contribute to the overall cause of desalinization.

Buckeye has been more than cooperative in showing its plant to anyone who wanted to learn. As a matter of fact, the press there in Buckeye, or in Pheonix, has termed the desalting plant as the town's greatest tourist attraction, because of the number of people who have visited it to inspect it.

That is the end of my presentation, and we thank you for the opportunity to present our views.

Mr. ROGERS. Thank you.

Mr. Aspinall.

Mr. ASPINALL. I want to thank you, Mr. Haden, for your statement. Yours was the first company and the first operation that this committee in Congress visited, prior to the installation of the Office of Saline Water. I think most of us got our interest at the Massachusetts Institute of Technology and your operations.

Do you have any contracts with the OSW at the present time?

Mr. HADEN. No, sir; we do not. As I mentioned, we have made two proposals to them, but we have no contract with them.

Mr. ASPINALL. You have never had a contract with them?

Mr. HADEN. Yes, sir; we had some years ago. I don't remember how many years ago, but at least 6 or 8 years ago was the last one we had, and the total amount of money involved was not large.

Mr. ASPINALL. At that time was the patent provision of the act comparatively the same as it is now?

Mr. HADEN. No, sir; it was much less restrictive than it is today.

Mr. ASPINALL. If we continue and have the program that you suggest, with the patent provisions and the law being what it is, you are not likely to be a participant?

Mr. HADEN. That is correct.

Mr. ASPINALL. And you are still for the program?

Mr. HADEN. Yes, sir.

Mr. ROGERS. Mr. Hosmer.

Mr. HOSMER. Where did Buckeye get this water from that they purified?

Mr. HADEN. From deep wells.

Mr. HOSMER. What happens to the residue, the effluent?

Mr. HADEN. They put it in an irrigation canal and I am not sure exactly what happens there, but I believe it is blended off and goes to crops that can support the extra salinity.

Mr. HOSMER. You and the other witnesses have talked to us about these various processes as though they were mutually exclusive and totally competitive. Has anybody done any work on combining the membrane to cut down your parts per million to some standard and

then pick it up with your process, or vice versa? Maybe by the combination of a couple of these processes we might get off better than if we used just one or the other.

Mr. HADEN. I would agree there is certainly a possibility of considering that. For instance, to take the effluent from the—the high saline effluent from electrodialysis. I don't know of any work that has been done on combining any processes.

Mr. HOSMER. If Mr. Di Luzio is around, maybe he could look into it. I believe he went home.

Mr. ROGERS. Mr. Reinecke.

Mr. REINECKE. You indicated that a 5 to 10 million gallon per day plant would be a good place to start, for obvious reasons. What is the approximate cost of a plant that size?

Mr. HADEN. About \$4 million.

Mr. REINECKE. Were you proposing that this would operate on sea water, or brackish water?

Mr. HADEN. Brackish water.

Mr. REINECKE. You have costs for sea water?

Mr. HADEN. We have only very rough costs on sea water because we concede that we are high cost on sea water. We have, today, only one plant actually operating on sea water, where they were willing to pay the extra cost because of the reliability of electrodialysis, on this particular feed, as compared to distillation. But our cost would be high so we haven't made a serious study.

Mr. REINECKE. The only application for electrodialysis is on the 3,000 parts per million?

Mr. HADEN. No, sir. We have some operating successfully at 10,000 parts per million. If there is a high proportion of sulphates, for instance, which scale distillation equipments they cause less trouble with us and therefore we are able to sell competitively at 10,000 parts per million, also.

Mr. REINECKE. What is competitive?

Mr. HADEN. I am talking about small plants, now, where equipment is being sold, say to oil well drilling rigs to supply them water, and the present commercial manufacturers of distillation equipment have been trying to sell the oil company their equipment versus ours.

Mr. HOSMER. This 5-million-gallon-a-day plant that you are talking about. Say you got whatever part per million you are talking about with brackish water, how much volume of water will you have to run through that plant?

Mr. HADEN. You are asking about the degree of rejection?

Mr. HOSMER. I am worried about this effluent and where to put it. Your brackish situation usually concurs with some sort of closed cycle area where you are pumping the stuff repetitively through your plant, or as you mentioned at Buckeye, sending it to somebody's agricultural property down the line.

Mr. HADEN. I can't give a categorical answer on that because it would depend upon the location and therefore the water that is selected because of the percentage of blowdown—that is the rejected water—on electrodialysis can vary from 5 to 50 percent of the water coming in.

Mr. HOSMER. It is pretty high. If you get 5 million gallons the less you would reject would be 105 million.

Mr. HADEN. That is the most I would expect to reject.

Mr. HOSMER. One for one?

Mr. HADEN. Yes, sir. My point is distillation has the same problem, too.

Mr. HOSMER. That is what bothers me. I don't think anybody has really discussed any answers in the hearings.

Mr. HADEN. There certainly is no one single answer to that problem. It would depend upon the locale.

Mr. HOSMER. Thank you.

Mr. ROGERS. On the first page of your statement you say in the last sentence of the second paragraph, "As enticing as this prospect is, we believe it is the consensus of experts in the field that a true breakthrough is unlikely and that a well-planned program of hard work and thorough investigation to build on current technology is what is needed to further progress in these directions."

Now, in that respect, do I understand you to mean that the time has come where we have reached the end of the line insofar as research has developed in the present know-how, and it is time for us to get over into the production?

Mr. HADEN. I didn't say that a breakthrough cannot occur. I said it is unlikely. Therefore, yet I think it is time for people to understand—people who have a need now, which is not so compelling that they are going out to buy plants, now, but whose need is strong, but who are delaying by reason of hope that something will be there around the corner next year, that these people should be given to understand that it is more likely that they should depend upon today's technology than to expect that breakthrough very soon.

Mr. ROGERS. Actually what I am thinking about is this: Are we not at the point in these processes where we are searching for, let's say, further refinement, and that refinement can be obtained either in modules or in production plants?

Mr. HADEN. Yes, sir.

Mr. ROGERS. You think then it would be useless to spend further money in going into large size demonstration plants?

Mr. HADEN. This is a relative thing, of course. The size of a module involved in a distillation plant which has been the main subject of testimony is in a totally different order of magnitude with that of electrodialysis. My testimony concerns electrodialysis in particular.

I agree that there is merit in testing of modules on the distillation. I do not believe that it is proper to do this in electrodialysis.

Mr. ROGERS. Do you feel that you have reached the point in electrodialysis at this time when you can project the optimum in size of the plant to get the greatest benefit—we will say a 10-million-gallon-per-day plant.

Mr. HADEN. The word "optimum" is a very specific word and I think the answer to that would have to be no, but I think it would be close enough to what can be expected so that we should go ahead on that basis, now. We have given ourselves a lot of thought to this particular problem, as to whether the size of the membrane stack, which is the module in electrodialysis, that we have today, is the right size or not. And when you scale up, at least in electrodialysis, you must give away something, too. Like life generally, you have to compromise.

Our feeling is it could be with time we would want to go to a larger stack but we are close enough with the unit we now have so that it is a realistic thing to go ahead.

Mr. ROGERS. As I understand it, in the electrodialysis process, when you scale up to a certain point you have reached the point, let's say, of diminishing returns and from that point on, the larger you would build, the more difficulties you would have?

Mr. HADEN. Yes. This is true within certain limits. The major costs involved in electrodialysis are, first, the cost of money. The capital to build a plant. Second, the cost of electricity, itself, and third, the cost of replacement parts, namely the membranes. Those are the three principal costs of such a plant.

With the cost of money, of course, it is not going to gain by module concept. We know what that is going to be. The cost of electricity is going to be independent of what the electrodialysis plant is. Except with scale, you will get a lower cost.

The question of the cost of the membrane is a factor in scaling up, here, which is unique to electrodialysis, and here we are not at the point of diminishing returns yet. When we get to the 10-million-gallon-a-day plant, however, we will then be close to the point of diminishing returns.

Mr. ROGERS. To put it in layman's language, if you had a customer who wanted to buy the water and he needed 30 million gallons a day, you could give him assurance of producing that gallonage to him at so much a gallon, based upon three 10-million-gallons-a-day plants?

Mr. HADEN. Yes, sir.

Mr. ROGERS. You couldn't possibly do it on a 30-million-gallons-a-day plant at the present time?

Mr. HADEN. That is correct.

Mr. ROGERS. One further question. Where did the binders come from?

Mr. HADEN. That is an ingenious little thing.

Mr. ROGERS. Is that something of yours?

Mr. HADEN. No, we just happened on those a short time ago. They are a product of the Beaverite Co. in Beaver Falls, N.Y.

Mr. ROGERS. I think that is the first time I have seen those.

Mr. HOSMER. Since you are a competitor with the distillation process, if Mr. Di Luzio gets his \$200 million and starts building modules, I think he ought to have some guidance on what is a reasonable size for a distillation module in terms of gallons per day or some other reasonable thing. He may think he can put up something about the size of the Rayburn Building. Do you have an opinion on that?

Mr. HADEN. No, I am sorry. We have enough problems of our own, so I really haven't given enough attention to that to be able to answer your question intelligently.

Mr. HOSMER. Do any of the other witnesses have any ideas on that? If they have, when they come up, I wish they would express them. I do think we should have some guidance. It is like buying a balloon. It might be big, or it might be small, depending on how much hot air is inside of it.

Mr. ROGERS. Thank you very much, Mr. Haden, for your presentation.

Our next witness is Mr. Bernard B. Smyth, General Atomic Division, General Dynamics Corp., accompanied by Dr. Ulrich Merten.

Mr. SMYTH. We welcome this opportunity to appear before you. I would like to suggest that Dr. Merten, who is the chairman of our chemistry department, make a short statement of about 4 minutes which would describe the technical status of our program, and I will make a statement of about 3 minutes.

Mr. ROGERS. Would you desire the statements that you have to be inserted in the record in full?

Mr. SMYTH. They are very short statements, sir. We will probably read them.

Mr. ROGERS. You may proceed, Doctor.

**STATEMENT OF DR. ULRICH MERTEN, GENERAL ATOMIC DIVISION,
GENERAL DYNAMICS CORP.**

Dr. MERTEN. General Dynamics Corp. began its study of reverse osmosis as a method of water desalination in 1961, at the John Jay Hopkins Laboratory of its General Atomic Division. Since April 1962, the program has included contract work supported by the Office of Saline Water. The total effort has been many-faceted, including research on membrane properties and behavior, development of membrane production techniques, conceptual design of reverse osmosis systems, and engineering development of system components. I would like to touch briefly on a few examples of the research and development work which has been carried out.

Membrane structure: At the time our work was started, it was well known that cellulose acetate membranes which were effective in desalination could be prepared by two rather different techniques. The two methods yielded membranes capable of producing water of comparable quality, but membranes prepared by the one technique yielded 500 times as much water per square foot of membrane per hour as did membranes of comparable thickness prepared by the alternate technique.

The high permeability membranes were examined by electron microscopy, and were found to consist of a porous mass of material which offers little resistance to flow of salt or water, overlain by a very thin layer of essentially nonporous cellulose acetate which is much less permeable to water than the porous mass, but much more permeable to water than to salt. This (fig. 1) is an electron micrograph of a membrane cross section, showing the dense cellulose acetate layer on one surface and the porous substructure beneath. The working layer is typically only 10 one-millionths of an inch thick, and the high permeability of these membranes is directly attributable to the thinness of this working layer. These results were published in the journal *Science* in 1964.

Membrane behavior: The mechanisms by which water and salts pass through osmotic membranes, and the reasons why water passes through them so much more readily than do salts, have also been

a subject of much study in our laboratory. This graph (fig. 2) compares the salt removal in an actual reverse osmosis system to the behavior expected on the basis of studies of fundamental membrane properties. The fact that the salt rejections actually obtained are not as good as the expected values shows that there is still room for much improvement in the technology even with presently used materials, and illustrates one of the areas in which research is continuing. This work, recently reported in the *Journal of Applied Polymer Science*, will also serve as a useful foundation for the recently intensified search for improved membrane materials.

Future membrane development. The cellulose acetate membranes now in use show permeabilities and salt rejections which appear to be quite adequate for brackish water desalination and many water reclamation purposes. Their long-term behavior as regards both these key properties is marginal, at best, for sea water desalination use. In addition, the lifetime of cellulose acetate membranes is limited. Research and development aimed at improving the present membranes and finding superior membrane materials is continuing.

Engineering development: Our early conceptual design studies of reverse osmosis systems indicated that the membrane support structure would be the major item of capital cost in a reverse osmosis plant built according to then-current design concepts. We therefore set out to develop a compact and inexpensive membrane support structure.

The result was a spiral-wound membrane module in which a pair of membranes are placed on either side of a flexible, porous support material. The resulting "sandwich" is wrapped around a central tube which also serves to drain the purified water from the porous support material after its passage through the membrane.

I have here a small, spiral-wound module (fig. 3 shows such a module being inserted into the test system of fig. 4). It contains 5 square feet of usable membrane area. This photograph (fig. 4) shows a system in operation in our laboratory at the present time, producing in excess of 1,000 gallons of desalinated water per day from a synthetic brackish water. The four long tubes in the photograph each contain 10 or 12 modules just like this one.

The present, 5-square-foot modules can be used to construct systems of any size if sufficiently large numbers are used. There is, however, economy in producing and handling fewer, larger units. These larger modules require important changes in design, and our present engineering development program is aimed in large part at making such changes.

Because the pressure vessels needed to house these modules are simply capped pipe sections, this approach to plant design provides substantial economies in capital costs. The cost of producing the membrane modules is being studied and development of inexpensive modules is proceeding. If we are successful in these efforts, as it now appears we will be, it is our belief that the modular reverse osmosis concept will prove to be a very economical way to desalinate water.

(The charts and photographs referred to above follow :)

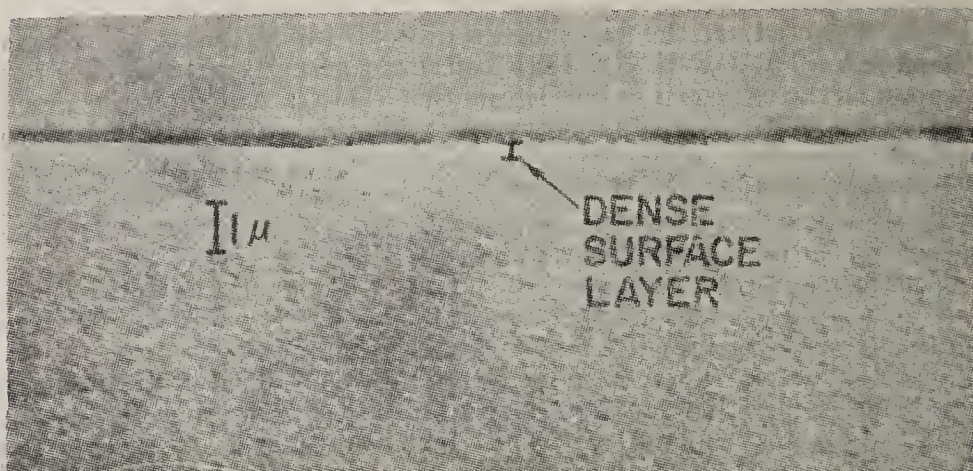


FIGURE 1.—Electron micrograph of cellulose acetate reverse osmosis membrane. Dense layer at top of picture is about 10 one-millionths of an inch thick, and is the working membrane.

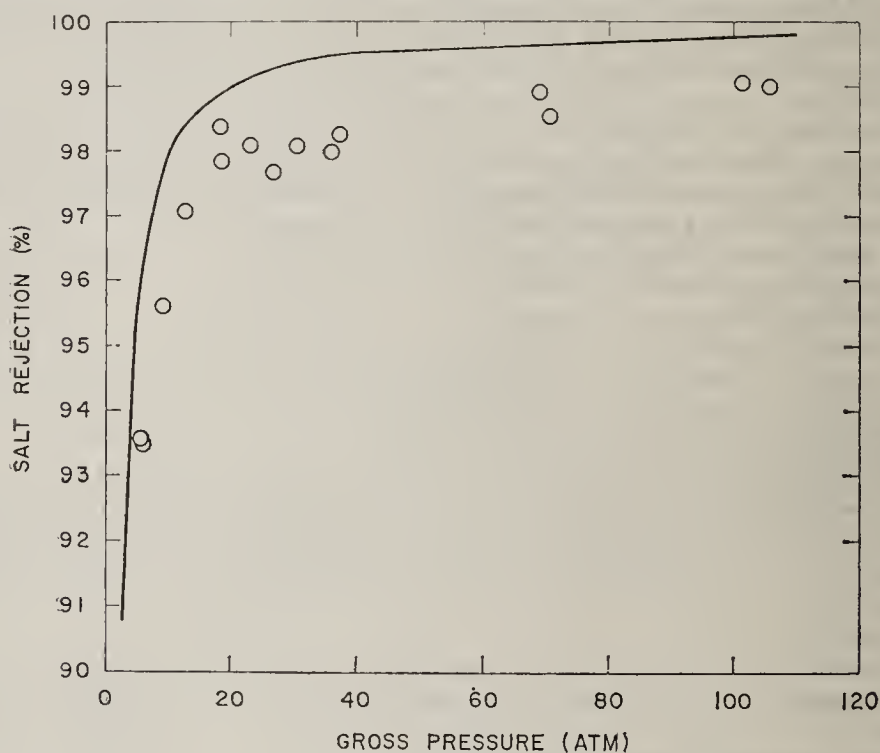


FIGURE 2.—Effect of pressure on salt rejection in reverse osmosis. Solid line is curve as predicted from known properties of cellulose acetate. Circles are experimental results.



FIGURE 3.—Spiral wound module being inserted into test system. The module is about 12 inches long and contains 5 square feet of useful membrane area.

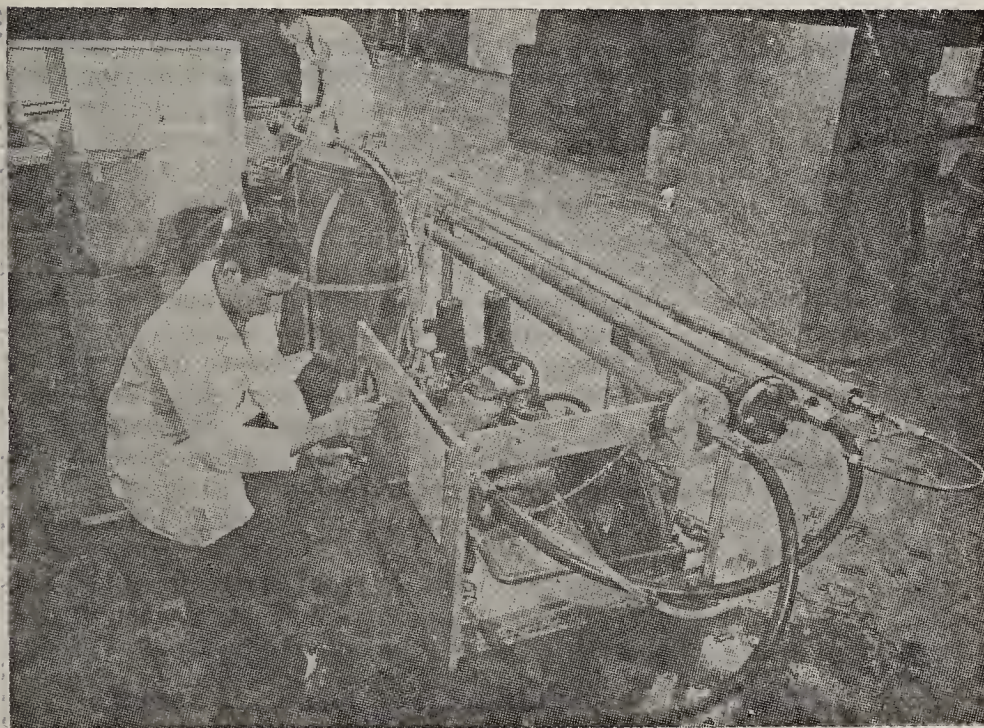


FIGURE 4.—Reverse osmosis test system. This system is designed for tests of brackish water desalination and waste water reclamation. It has produced in excess of 1,000 gallons per day of desalted water from a synthetic brackish water source in recent tests.

Mr. SMYTH. We are using the word "module" a little differently there than has been used otherwise.

Mr. ASPINALL. We can understand that.

STATEMENT OF BERNARD B. SMYTH, VICE PRESIDENT, GENERAL ATOMIC DIVISION, GENERAL DYNAMICS CORP.

Mr. SMYTH. The reverse osmosis program at General Atomic Division of General Dynamics is an integrated research and development effort within the general desalting program of OSW in which the first and largest efforts have been directed toward gaining a basic understanding of the reverse osmosis process and only more recently toward application of this knowledge to the engineering requirements of plants.

This technology at General Atomic represents a total investment over the last few years of about \$1.2 million, of which about two-thirds has been by OSW and about one-third by the company.

The developmental approach being used in our activities has purposely delayed commitment to an engineering design concept until late in the program when the fundamental building blocks were known; however, it promises a compensatingly rapid rate of development now that the plant engineering phase has begun. The plant and process engineering has progressed far enough to permit General Atomic in recent weeks to offer to provide on fixed-price bases complete reverse osmosis test loops in sizes up to 5,000 gallons per day of product water for experimental uses by persons interested in the Government's program.

As the next major step in our OSW engineering program, we plan to propose in the next few weeks, for immediate construction on a fixed-price basis, an experimental pilot plant of 50,000-gallon-per-day capacity with pressures available up to 2,000 pounds per square inch. We also plan to propose construction of a larger brackish water system which will allow developmental demonstration and testing of essential components in addition to the reverse osmosis modules themselves.

These proposals will be directed at the substantial developmental jobs yet to be done. For example, in the important area of reverse osmosis for municipal water supply, two major tasks to be accomplished are: (1) demonstrating all elements of reverse osmosis plant technology, particularly demonstrating the unique design features of the major components such as recovery turbines and pressure vessels; and (2) demonstrating the economics of reverse osmosis plants. We believe that construction and operation of plants of at least 250,000-gallon-per-day capacity will be required to furnish information directly relevant to these objectives.

The question might arise at this point of how the Federal Government's activities might best encourage a timely assumption by industry of a larger responsibility for the continued development of this technology. It is clear to me that the reverse osmosis program of the Nation certainly has been accelerated by support given in recent years by OSW. It is equally clear that should the rate of governmental direct investment be lessened substantially, private enterprise would continue the further development of this technology; however, it would be continued at a different rate, probably more slowly, par-

particularly if the Federal Government chose to give greater encouragement to other methods of desalting.

Municipal water supply is a use of reverse osmosis which the OSW program has identified as being particularly promising. Consequently, a near term goal for the Federal program might be sponsorship of research and development at least until a plant useful to small municipalities has been demonstrated. This criterion gains support from the fact that the owners and operators of municipal water supply plants will commonly be public or quasi-public organizations which are limited in the degree of risk which they can assume. The technical resources available to them are also frequently rather limited. Again, we believe that the operation of reverse osmosis plants of at least 250,000-gallon-per-day capacity will be necessary before that measure is met.

Once the Federal Government was committed to construction and operation of one or more of these plants for municipal water supply purposes and to the research and development which would accompany it, it would be reasonable to expect industry to accomplish a good share of the directly allied work, such as improving membranes and components and establishing production techniques and facilities for these purposes.

Use of reverse osmosis in larger systems has not been thoroughly studied. Since the beginning reverse osmosis has been considered to be particularly attractive in smaller sizes. However, we believe that the advantages of reverse osmosis relative to other known methods of desalting will probably be found to exist in large sizes as well as in small sizes.

The design concept of self-supported spiral membrane modules employed by General Atomic in the OSW program is directed toward minimal capital cost with simple operating procedures and this, together with its inherently low energy requirements, should be directly relevant to large as well as small plant economics.

Accordingly, decisions on Federal investment in large as well as small reverse osmosis plants should rest essentially on the rate of development which the Federal Government wishes to stimulate, in a manner similar to comparable decisions on other methods of desalting.

Mr. ROGERS. Thank you, Mr. Smyth.

Mr. Aspinall?

Mr. ASPINALL. Mr. Smyth, has the work covered by the \$1.2 million, two-thirds of which has been furnished by the Office of Saline Water, been the extent of your participation in the Office of Saline Water endeavors?

Mr. SMYTH. Yes, sir. We have under the Atomic Energy Commission some activity in reactors, but that is separate.

Mr. ASPINALL. Do I understand that the 5,000-gallon plant and the 50,000-gallon plant you talk about in your statement are to be financed by you or partly by the Office of Saline Water?

Mr. SMYTH. The 1,000-gallon plant we picture here happened to have been financed by our company. The ones that are smaller than the 50,000-gallon-a-day unit, which we referred to in our statement, are those which may be funded by private persons, universities, or other Government organizations.

The 50,000-gallon-a-day pilot plant, which is an experimental tool set forth in Mr. Di Luzio's plan for the future, would probably be funded by OSW.

Mr. ASPINALL. Do you have any difficulty with regard to the patent provision in the present law?

Mr. SMYTH. We have developed our program at General Atomic in cooperation with the Office of Saline Water knowing what their patent policy is and accepting it. This does cause us problems but we do not feel these are insurmountable.

Mr. ASPINALL. I understand some of your activities might be with your own money and some of your activities might be under contract with the Office of Saline Water. If so, in one instance you would be subservient to the law and in the other you would not be.

I just wondered if you can carry this on without too much difficulty.

Mr. SMYTH. There will be difficulty as was mentioned earlier by another witness. The patent policy of OSW does require background patent rights. On the other hand, there are certain areas of our activity which the Department of the Interior has not been interested in particularly, such as production techniques, the production machinery we use to make the membranes, et cetera.

Mr. ASPINALL. The gist of your statement is that in certain operations you believe you can carry on without any further Government cooperation, and yet in perhaps larger and more exotic possibilities you think the Office of Saline Water should be continued and aid given. Is that right?

Mr. SMYTH. I would say that if the research and development support by the Office of Saline Water were to stop today I am confident that there has been enough success shown in reverse osmosis today that this technology would continue and would be available to the Nation.

The time scale upon which it would be available I do not know. It would probably be later.

On the larger plants, if the Federal Government desires to continue a research and development program they should not count reverse osmosis out because it does have applicability to larger plants, we believe.

Mr. ASPINALL. That gets us to that part of your statement where you suggested that the progress might be slower without Government financing. I wondered if it might be so slow as to endanger the complete operation. Your answer is that you think private enterprise would pick it up as the product is needed.

Mr. SMYTH. Yes, sir; perhaps at a rate which would be slower than Mr. Di Luzio would like to have for satisfying the public interest.

Mr. ASPINALL. Thank you.

Mr. ROGERS. Mr. Hosmer?

Mr. HOSMER. Do you have any history on the life of these membranes you have been using?

Mr. SMYTH. Yes, sir; I will ask Dr. Merten to answer that.

Dr. MERTEN. The lifetime membranes has been a subject of considerable study. The longest continuous run that we have, I think, is about 11 months now. We believe on the basis of our experience and on the basis of auxiliary studies, trying to understand what the processes are which lead to membrane deterioration, that lifetimes of a couple years or perhaps more are in the cards.

Mr. HOSMER. Is there any temperature effect in this process?

Dr. MERTEN. Yes; on the rate at which water passes through the membrane. That increases with temperature. There is also an effect on rate of membrane deterioration.

Mr. HOSMER. With higher temperatures?

Dr. MERTEN. Yes.

Mr. HOSMER. But your process depends essentially on pressure?

Dr. MERTEN. That is right.

Mr. HOSMER. Why couldn't you take some large modules out and sink them in the bottom of the sea at the appropriate depth, get the pressure you want, and as the fresh water comes in pump it up to the beach?

Dr. MERTEN. That is one thing one might do.

Mr. HOSMER. Has anybody ever looked into it? I just thought of it myself.

Dr. MERTEN. Yes; it has been looked at. In fact, you can think even further than that. There is a difference in density between salt water and fresh water. If you go deep enough the product will even float to the surface but you have to go awfully deep.

I don't know that one has done a detailed economic study. Those who have looked at it in cursory fashion have concluded it is better to buy electricity.

Mr. REINECKE. At what pressures do you operate? Do you work in the same pressure range?

Dr. MERTEN. More or less; for sea water desalination we talk about 1,500 p.s.i.

In brackish water we have used lower pressures. We usually operate at about 400 p.s.i.

Mr. REINECKE. The proposed program calls for 41 percent of this money to go to distillation, 30 percent for other R. & D., and the rest for reverse osmosis. How does this strike you?

Mr. SMYTH. As brand X in the reverse osmosis field, as one of the two being considered, if the flow of money were to satisfy the program which we consider to be the appropriate program I think we would be very satisfied with that.

I would like to elaborate on that if I may.

We feel there are two points in Mr. Di Luzio's proposed plan, which should be brought to your attention. The next step, as we have said, is a pilot plant of 50,000 gallons per day.

The plan by OSW calls for one of these pilot plants in 1966 and another pilot plant in 1967.

You have heard testimony by another contractor and by us that we are both ready for these pilot plants. We would both be ready for them in fiscal year 1966.

We feel these pilot plants are experimental tools which are very valuable to the contractor, and if these tools are not available to us when the time is ripe then we risk a standstill in our development of our development of our technology until these tools are available. That would relate to the program immediately ahead.

Also in the program which Mr. Di Luzio has laid out he talks about another pilot plant which would be earmarked for salt water purposes, the two earlier ones being for brackish water. This pilot plant also would be a 50,000 gallon per day pilot plant. It would be available in 1968, I believe.

Our approach on this would be to build pilot plants this year, fiscal 1966, beginning July 1, which are flexible enough to furnish information relative to both brackish water and salt water, and for this reason we have mentioned in our statement that the pilot plant we would propose would have flexibility and pressures up to 2,000 p.s.i., which, as you recognize, is greater than that which we would use for brackish and even greater than that which we would use for salt water.

Mr. REINECKE. We have been talking about water costs anywhere from 20 cents to \$1 per thousand gallons. This is delivered at the plant. I am interested in knowing what the distribution costs would be which are added to give us an effective price to the consumer. Thirty-cent water may not be quite as cheap as we think it is and the distributors may have another 10 or 15 cents cost there.

Mr. ROGERS. When you talk about 20-cent and 25-cent water you are talking about water prices as they exist today in a great number of the municipalities. Whatever the consumer cost is today would be related to the matter held up earlier.

Dr. BARON. It depends on the quantity and the distance. Some of the studies go anywhere from 5 to 15 cents a thousand gallons for distribution, including pumping, and so forth.

Mr. REINECKE. If a given desalting plant delivered water to the main pipeline into such and such a city, how much cost will be added on top of that? What range of cost will be added? The consumer obviously has to pay something over the delivered cost. I am interested in knowing how much of an overlay we are talking about.

Dr. BARON. If you have the dual purpose power and water plants about 40 miles away from the city, you produce your water in these large plants at around 30 cents. You add roughly another 10 cents to take it from the dual-purpose plant into the city.

Then the water district has its own administrative costs on top of that and that could be another 15 to 20 cents on top of that.

Mr. ROGERS. I think what we are talking about in this whole process is this: Once you get water desalinated at a cost which is even close to what people now are paying the battle would be won. Even at 10 cents a thousand gallons above what you are paying in most municipalities throughout the United States that would be so, and that is if we are using municipal and industrial water.

Mr. REINECKE. In many large cities we are paying 9 to 10 cents a thousand gallons.

Mr. ROGERS. Thank you very much.

Our next witness is Mr. John W. Simpson, vice president, Electric Utility Group, Westinghouse Electric Corp. This statement will be presented by Mr. Roy E. Gaunt, manager, Water Province Department, Westinghouse Electric Corp.

STATEMENT BY ROY E. GAUNT, MANAGER, WATER PROVINCE DEPARTMENT, WESTINGHOUSE ELECTRIC CORP.

Mr. GAUNT. Mr. Simpson regretted he was unable to be here.

My name is Roy E. Gaunt. I am a manager of the Water Province Department of the Westinghouse Electric Corp. Our work in water desalting plants is my direct responsibility.

To save time I shall not read the entire statement by Mr. Simpson but present it to the committee.

Mr. ROGERS. We shall insert it in the record as though read.
(Mr. John W. Simpson's statement follows:)

STATEMENT OF JOHN W. SIMPSON, VICE PRESIDENT, ELECTRIC UTILITY GROUP,
WESTINGHOUSE ELECTRIC CORP.

My name is John W. Simpson, and I am a group vice president of Westinghouse Electric Corp. More specifically, I direct the engineering, manufacture, and marketing of basic electrical equipment for heavy industries. Our work in water desalting plants is one of my responsibilities.

I thank you for this opportunity to appear before the committee. Westinghouse is in complete accord with the objectives and in general accord with the approach of the Federal water desalting program as set forth by the Secretary of the Interior and the Office of Saline Water. We believe that the President's request for a "vigorous program of economic desalting" deserves congressional support.

We have had a half century of interest and experience in the purification of water. This is because the boiler that supplies steam to a steam turbine must be fed ultrapure water.

Westinghouse began to purify brackish and mineral-charged water for electric powerplants in the early 1930's, using submerged tube-type evaporators. By the middle of the 1930's, our water evaporators were in common use by utilities and industrial plants throughout the country.

In 1948, we began to research, develop, and build the first large-scale plant for distilling ocean salt water. We did this for the Sheikdom of Kuwait on the Persian Gulf. Our plants in that area are now producing slightly more than 5 million gallons of pure water per day.

We have completed, are building, or have signed contracts to build flash-evaporator desalting plants with a total daily capacity of nearly 14 million gallons. One of the completed plants was the Office of Saline Water installation at Point Loma, Calif. This plant was supplying 1.4 million gallons of water per day to San Diego's water system before it was moved to Guantanamo Naval Base, Cuba. There we have added two additional units to bring total daily water production at Guantanamo to 2¼ million gallons.

Most Americans who are at all knowledgeable on the subject agree and understand, I think, that certain of our communities have a serious shortage of water; that hundreds of other communities are now drinking water that falls considerably short of recommended purity levels; that with the rapidly growing need for water the problem could become one of catastrophic proportions unless something is done; and that an important part of the problem will be solved if we can economically convert ocean salt water into potable water. They realize also, I believe, that what we do to help solve the worldwide problem of water resources will be a service to all mankind and a contribution to the image of America everywhere.

This leaves us with two basic questions to consider. First, what is the present and potential capability of American industry in the technology of water conversion? That is, can we convert sea water on a practical, economical basis? Second, what kind of water conversion program should we carry out?

As to the first question, speaking for Westinghouse, we consider that our technical capability is excellent. We can build plants that will purify ocean salt water. We know this because we are doing it.

From building the Point Loma plant and from the knowledge gained from our other installations, we know that there is no technical limitation on size. Now the time is right to move upward in size. It is technically feasible now to build desalting plants as large as anyone wants—50 million gallons per day, or 100 million gallons, or 150 million gallons, or larger—with life expectancy comparable to that of powerplants. The pioneering research work has been done. What remains to be done is a rigorous engineering effort—an effort to build ever-larger plants to verify the point at which maximum advantage is gained from economics of size. Today's cost of about \$1 per thousand gallons in a 1-million-gallon-per-day plant could be reduced, we estimate, to from 30 to 35 cents in a plant of 50-million-gallon-per-day capacity, based on like conditions. This would be water delivered at the water desalting plant boundary.

Thus the groundwork has been laid for an acceleration of the water conversion program as proposed by the President. This is a remarkable technical achievement, and all the more so because it has been done with a comparatively modest expenditure of Federal funds. Until a few years ago, of course, industry was conducting its research, development, and construction with its own money and without Federal support. When the Office of Saline Water began its program, it did so with a relatively small budget and an even smaller staff. Yet this small force, spending less than \$7 million for demonstration plant construction and working closely with private industry, initiated and managed a five-part prototype program of tremendous importance to the Nation.

This program has shown plainly that water can indeed be produced at far less than the \$4 per thousand gallons which once was considered a realistic price. And, more important, it has produced basic knowledge about various processes and has shown what areas need more research and what areas need engineering as the next step forward.

The question that faces the Nation now is the crucial one: What direction should the water conversion program now take? In Mr. Kenneth Holum's words, "We have reached a point in the Department's desalting program where important decisions must be made."

In the opinion of Westinghouse, the best and fastest progress to bring down costs in water desalting in the foreseeable future will be made in multistage flash distillation units such as that used at Point Loma, Guantanamo Bay, and in many other installations.

We have been conducting research in other water conversion methods for some years, including reverse osmosis, freezing, and vapor compression. We also have investigated the electrodialysis process. We are pushing ahead with construction of multistage flash distillation plants because we have found that no other process presently approaches the technical feasibility and the overall economy of this method; because it is the one process that has proved itself in operation; because it is the only system that is now producing water in volume; because it is 2 to 5 years ahead of the other systems; because it lends itself to combination with power production; and because it is the only system that is sufficiently developed and ready today for large-scale plant construction with firm price, performance, and completion date guaranteed by the builder.

This process has the additional advantage of lending itself well to future modifications as new advances in technology occur. It will not be rendered obsolete, for example, as we learn how to increase operating temperatures above the maximums possible today—an advance which lies ahead and which will substantially reduce the capital cost of plant construction for a given water output.

We believe, secondly, that there is a great potential for large plants that produce both electricity and pure water. To desalt water you need heat. A powerplant rejects well over half of its heat input. By every evidence of experience, technology, and economics, these two plants complement each other and belong together. It makes sense to take the flow of turbine steam in its lower stages and divert it in whole or in part for the production of fresh water. It goes without saying that there must be a market for a large amount of both water and power.

For those areas of our country that lack resources of fossil fuel and need massive amounts of water and power, there can be great economic and technical advantages in marrying the large atomic powerplant and the large water desalting plant. We believe that, as this technology develops and the need increases, this is the direction that water desalting will follow in such areas.

One basic factor to consider here is that the atomic powerplant lends itself admirably to the economy of size. The equation is quite simple and definite: the larger the atomic powerplant requirement the lower the unit production cost, whether measured in B.t.u.'s of heat, kilowatt-hours of electricity, or gallons of water. On the other hand, there is a more moderate reduction in unit cost as the conventional powerplant increases in size. There appears to be almost no significant reduction as a result of increasing the size of installations that convert water by processes other than distillation.

The nuclear desalting plant can be a dual-purpose installation for the production of electricity and water, or it can be a single-purpose plant for the production of water alone. But in either case, atomic power must pass the test of the marketplace, just as it is doing now in the powerplant field. There is no magic correlation between a nuclear reactor and a flash evaporator—that is to say, a nuclear reactor is still the same heat source, whether it is hooked up to steam

turbine or an evaporator. The cost of desalting water is largely the cost of generating the heat, and the evaporator cares not at all where that heat comes from. Naturally, the owner will want the heat to come from the fuel that is the most economical in his given region and circumstances: coal, oil, natural gas, or nuclear.

As a veteran in the atomic power business, I must add that I see no reason to think that the light water reactor will be supplanted as the most satisfactory source of nuclear heat for water desalting in those situations where nuclear is the logical economic choice.

In commenting on the proposed water conversion program, we will make only two recommendations. The first concerns plant construction and the second, research and development.

First, we recommend construction of a large water desalting plant now as the first prototype in a large plant development program.

And, second, we recommend that the Office of Saline Water continue and expand its research program on methods of converting water.

Building the big plant now is, we believe, a crucially important step in the advancement of water conversion technology.

At this point, I would like to make clear that my remarks in favor of the early construction of a large plant relate entirely to the technical requirements of the desalting art. My company is able and willing to work for and with customers for such plants, whether they be from industry or the Government, or from both in some joint arrangement. Consistent with our longtime belief in the merits of our system of private enterprise, I would hope that private industry would see fit to build such a plant.

We recommend that this plant be built to a daily capacity of not less than 50 million gallons. Naturally, we recommend that it be built to fill an actual need in or near one of the large communities on an ocean coastline.

What are the reasons for building a full-scale plant at this time?

The primary reason for building it is that this is precisely what the water program needs at this time. We are at the point where we have to learn what only a large-scale effort can teach us. The greatest advance we can make now will come through building the large plant.

Westinghouse is technically ready to build the plant. The Nation wants to see it built. There is very little to be gained by delay. We don't have to wait for some important discovery. There are no major problems of technology to be solved. In our opinion, the time to begin reaping the benefits of existing technology and to break the cost barrier is right now.

Where there is positive effort to improve at each step, every plant that is built in a new art like this should be markedly better than the one before it, both in performance and cost. Point Loma was considerably better than the first-generation plants at Kuwait. When the third generation plants are built, they will be considerably better than Point Loma. Such progress will continue even after we have mastered this new art and are building huge desalting plants routinely, because no technology is static and there is always more to be learned.

We learn by doing. For example, after Point Loma was in operation, the OSW began to experiment with the technique of chemically pretreating the seawater before it became a river of hot brine. With an investment of only \$22,000 it increased Point Loma's capacity by 40 percent and broke through a temperature barrier that was blocking the path to more economical water conversion. This barrier had been set by the temperature at which severe scaling occurred. Further advances like this are what we need to achieve a quantum advance in the water desalting program.

When the 50-million-gallon-a-day plant is built, a true economic benchmark will be established by which to positively determine the economic trade-off between plant size and water cost. Such a benchmark is a necessary yardstick by which we can measure our true progress in applying the knowledge accumulated to date. And when this plant has been built, and when its technical and economic feasibility has been demonstrated in actual operation, we believe that coastal communities in need of water will move to build more such plants which will be even better.

The first plants in a new art are always overdesigned to some extent, to allow for an extra engineering margin. They are heavily instrumented to permit special test procedures. Test data show, step by step, what the materials will do, which are better and which are worse. On the next plant, the engineering margin is reduced and more effective use is made of the materials.

The obvious but highly important point here is that there is no substitute for hard, practical experience. Building a plant on paper, or as a test model is one thing; building it to full scale in actual fact is a very different matter. If we had built Point Loma only on paper, there would be no flash evaporator plants operating today at 250 degrees. If we had built it only in a laboratory, I would not be able to make the statement that I am making here today.

There is a clear parallel between the development of atomic power as it stood a decade ago, and the development of water desalting as it stands today. This is true despite the infinitely more difficult problems encountered in building a nuclear reactor. I remember that on July 9, 1953, Mr. Gwilym A. Price, then president of Westinghouse, and Mr. Charles H. Weaver, then manager of our Atomic Power Division, testified on the atomic power program before the Joint Committee on Atomic Energy. The land-based prototype of the Nautilus reactor had gone critical 2 months earlier at the Idaho Test Station, thus demonstrating that the project was feasible. In his testimony Mr. Weaver stressed, as I have today, the wide gap between making paper studies and actually building a full-scale installation. He described one of the most significant factors in the satisfactory progress of the Nautilus project. We were given, he said a definite goal—"a reactor to build instead of studies. And the goal was definite as to time also, with a working schedule * * * established."

Another reason for building a large-scale desalting plant now is related to the probable consequences of carrying forward a water program without such a plant. First, our country will lose its position of technical leadership, and second we will risk fragmenting our efforts.

We must remember that other countries are conducting strong water desalting programs. If we delay building a large-scale plant, other countries will be delighted. I mean to say that the competitive rivalry that is shaping up for this world market is as clear cut as it is in the supersonic air transport race or in atomic power. One thing is certain: large plants are going to be built and sold—if not in our country, then by some other country.

I know of no other field which, on a worldwide basis, is a subject of greater concern and is receiving more vigorous and enthusiastic attention than that of water resources. It is an area in which international cooperation can be developed and it is imperative that the United States maintain leadership.

Beyond this, I fear the consequences of spending too large a proportion of our effort—time, money and talent—on small pilot plants and study projects. At the end of such a program we still would not have the knowledge that comes only with building and operating a large desalting plant. We would not have demonstrated that large plants can produce low cost water to satisfy a real community need. We certainly would not have carried out the "aggressive and imaginative program" President Johnson has called for. In our opinion, such a program should include specific projects with firm and definitive goals, including both plant construction and research and development. The toughest and at the same time the most meaningful goal will be a target cost for water under specified conditions.

Speaking for Westinghouse, I will state for the record that we are prepared to submit a firm bid on a large desalting plant at this time—50 million gallons per day, or 100 million, or 150 million, or larger if desired. We will do this for a single-purpose desalting plant fueled by coal, oil, gas, or a nuclear reactor. We will do it for a dual-purpose power-water plant fueled by coal, oil, gas, or a nuclear reactor. Construction of this plant could begin immediately.

We will submit this bid on a turnkey firm-price basis, with warranted capacity, warranted heat rate, warranted power consumption, warranted chemical consumption, warranted purity and completion date. If the customer desires, we will also operate the water desalting plant for him. This ties down all the factors that go into determining the cost of producing water. In our opinion the cost of water from a plant bought on these terms can satisfy real and present needs in certain areas of the world today.

We realize the significance of such a statement as this. We are willing to make it because of our very considerable experience in the research, development, design, construction, and operation of water desalting plants, of power generation equipment, and of nuclear reactors—in short, all parts of the total plant.

Our other recommendation on the water conversion program is that the Office of Saline Water continue, intensify, and expand its research program on promising methods of converting water. We must find economic ways of purifying

the brackish and mineral-charged water that is found in many inland areas of our country. The plants required to treat water that is not so impure as ocean salt water will presumably be of smaller size.

While any research and development program should, of course, be careful to look at all possibilities, it is important that major emphasis be put on those processes which appear most promising. The mere fact that a particular technique is novel or different does not necessarily warrant giving it attention that would detract from the principal efforts.

Research will also be required to find some practical method of reducing stream pollution by removing mine acids and other industrial wastes at the source. Westinghouse is actively engaged in such research.

As we see it, the water conversion program is now ready for a big step forward. The feasibility study recently ordered of a large nuclear-power and desalting plant for the Metropolitan Water District of Southern California is an evidence of an accelerating program, and it may provide the breakthrough in size the program needs. The bilateral agreement recently signed with Israel to conduct studies for a proposed nuclear-power and desalting plant is another example of this progress.

In closing, I would like to refer once again to the great and overriding need for this program. The whole Nation was shocked this spring to read that New York City's reservoirs were only 40-percent full, and that water use there had to be limited. The availability of fresh water is obviously going to be a very great national problem in the years ahead. It is reassuring that the problem is now receiving broad national attention, but much work lies ahead.

I thank the committee again for the privilege of testifying.

Mr. GAUNT. I would like to insert at this time, in addition to the statement just read, a statement that will tend to clear up a misunderstanding which occurred in the Senate hearings earlier this week:

Westinghouse has benefited tremendously from its participation in the OSW program. The lessons we learned by building and putting into operation the Point Loma plant have been invaluable to our commercial operations in the water conversion field. Many of the OSW contracts relate to areas which we are not actively pursuing and are, therefore, of no practical value to us. Nevertheless, we follow such work closely in order that we may profit from any results which could affect our business. Some of the OSW contracts are aimed at technology in which we consider ourselves already knowledgeable, having pursued the same objectives through company-funded efforts.

I thank the committee again for the privilege of testifying.

Mr. ROGERS. Thank you, Mr. Gaunt.

I gather from your statement that you think it would be foolish to go further into pilot plants, modules, or demonstration plants insofar as this process is concerned?

Mr. GAUNT. Mr. Chairman, I would not say it was foolish, no.

Mr. ROGERS. I understand that, but it would be impractical. We are at a point where we have worked out the research so it is time to move into production rather than do further research.

Mr. GAUNT. It is the feeling of my company that we should immediately proceed to build the big plant. We feel we have the technology today to build a good big plant. We think that later on we will build a better big plant.

Mr. ROGERS. What will be the cost? Have you any estimate for a 50-million-gallon-a-day plant?

Mr. GAUNT. This would be determined only after you got an exact site for it and determine what the steam cost would be and then optimize the efficiency of the plant.

Mr. ROGERS. Certainly you have some estimate in mind, some present-day costs? Don't you have a per-million cost?

Mr. GAUNT. I would say in the neighborhood of \$30 to \$40 million.

Mr. ROGERS. It would be foolish, then, if you are going into this, to spend \$30 to \$40 million for a plant when you can find out the same things, so far as refinement of existing processes was concerned, it would be foolish to spend \$5, \$6 or \$7 million on one, two, three, or four further demonstration plants.

Mr. GAUNT. We feel there is more than one way to do this thing. We are merely saying that we think this way would be the fastest way to get the existing technology into an operating plant, satisfying a real need.

Mr. ROGERS. And you feel it would be the cheapest way?

Mr. GAUNT. In our opinion, yes.

Mr. ROGERS. That is because you figure you will have to build the plant, anyway, and the quicker you do it the better?

Mr. GAUNT. It is our feeling that we have learned tremendously from building these plants. If we had not built Point Loma and it had all been paperwork studies, we still would be doing paperwork studies.

Mr. ASPINALL. How much money have you had from the Office of Saline Water since the beginning of this program?

Mr. GAUNT. Something under \$2½ million, about \$1.7 million of which was related to the Point Loma construction project.

I am sure you are aware that was not a research contract but a firm bid price.

Mr. ASPINALL. How many people do you have in your organization working on this program at the present time?

Mr. GAUNT. On the water program?

Mr. ASPINALL. Yes.

Mr. GAUNT. Our water program consists of about 50 people, considering all aspects of our corporation.

Mr. ROGERS. How many of these are financed entirely or partly by your own funds?

Mr. GAUNT. I would say at least 40 of these are being financed by our own funds.

Mr. ASPINALL. Are you the contract builder of the plant at St. Croix of the Harvey Aluminum Co.?

Mr. GAUNT. Yes.

Mr. ASPINALL. It seems you have something going there.

Mr. REINECKE. Are you in agreement with Mr. Di Luzio's statement that there is a design for about 80 cents a thousand gallons?

Mr. GAUNT. I couldn't answer as to the exact water cost. It would be something less than the Point Loma plant.

Mr. REINECKE. You feel we should build a 50-million-gallon plant? Do you think we should build such a plant until we feel we have a product we can sell?

Mr. GAUNT. No plant should be built unless there is a market for the water.

Mr. REINECKE. Then before we take steps to build the plant we have to make this complete study.

Mr. GAUNT. This is my understanding of what the Metropolitan District Water Study is, to determine the practical use for the water at a given cost.

Mr. REINECKE. Yesterday, in talking to Mr. Di Luzio, he mentioned the 80 cents price, and then to bring it into the realistic 30 cents range he said he thought the cost of steam could be reduced to 15 cents a million B.t.u.'s. Do you agree with that?

Mr. GAUNT. I think it is practical to obtain steam from a large power-water combination to obtain this steam for 15 cents a million B.t.u.'s.

Mr. REINECKE. Is this a realistic price or gimmicking the cost of the electricity?

Mr. GAUNT. I feel that is based on a reasonable assumption which Southern California Edison Co. made in their statement to the Atomic Energy Industrial Forum last year.

Mr. REINECKE. What were they selling the power for from the combination plant?

Mr. GAUNT. I don't recall the exact power cost.

Mr. REINECKE. Power would be in the vicinity of 3 to 4 mills.

Mr. GAUNT. I don't believe they were that low in power.

Mr. REINECKE. I wonder if we are not getting some accounting practices worked on us here.

You feel we should go right into the large plant. Do you feel it would be reasonable for the Office of Saline Water to contract with some large city, such as Los Angeles, and perhaps split the cost, or go part way, to accomplish their results and at the same time allow some large city to pick up the other half of the cost? Will there be a conflict of objective here?

Mr. GAUNT. I see no conflict.

Mr. ASPINALL. Did Westinghouse build a saline plant prior to 1952?

Mr. GAUNT. Yes; we did, Mr. Aspinall.

Mr. ASPINALL. Can you tell me what the cost of the water was before 1952 as produced at your plant?

Mr. GAUNT. Any plants we built prior to 1952—I have no information. The people who bought them were not too interested in water cost.

Mr. ASPINALL. Would you get us that information?

Mr. GAUNT. I shall be glad to supply it.

Mr. ASPINALL. That is all I have, Mr. Chairman.

Mr. ROGERS. Thank you very much, Mr. Gaunt.

Our next witness is Dr. S. Baron, vice president, Burns & Roe, Inc.

STATEMENT OF DR. S. BARON, VICE PRESIDENT, BURNS & ROE, INC.

Dr. BARON. How would you like me to handle the testimony? Shall I summarize it?

Mr. ROGERS. It would be very well if you could.

Without objection, your statement can be put in the record the same as if it had been read.

(The statement follows:)

STATEMENT OF DR. S. BARON, VICE PRESIDENT AND DIRECTOR OF THE NUCLEAR AND PROCESS ENGINEERING DIVISION AT BURNS & ROE

Mr. Chairman, my name is Dr. S. Baron. I am vice president and director of the Nuclear and Process Engineering Division at Burns & Roe. In this capacity, I am responsible for the company's technical activities in the nuclear and desalting fields.

For the information of the committee, Burns & Roe has been very active, for the past 5 years, in the desalting field, including such projects as management and operation of the Point Loma plant for OSW; design and construction of the Gitmo desalting plant as subcontractors to Westinghouse; operation of the Gitmo plant; design construction, start-up operation and financing of desalting plant in the Canary Islands; engineering and feasibility study of desalting plant for the Florida Keys for OSW and AEC; as well as a variety of desalting studies for Long Island, Virgin Islands, Okinawa, San Andres, Puerto Rico, OSW (parametric studies). Presently we are carrying out one of the 50-million-gallon-per-day conceptual studies for OSW.

In addition to the above activities, Burns & Roe has supported, at its own cost, research and development of the controlled flash evaporator process through its research company called Scientific Development, Inc. The laboratory developments were successfully demonstrated in a 15,000-gallon-per-day pilot plant dedicated a few months ago in Puerto Rico for the Puerto Rico Water Resources Authority. We are now completing the large module designs of the controlled flash evaporator which will produce in a single stage around 170,000–250,000 gallons per day. A number of utilities are interested in this concept since it utilizes the waste heat in the powerplant cooling water for fresh water production.

Based upon our experience in the desalting field, we would like to express our opinions and thoughts regarding the engineering design and R. & D. programs proposed by the Office of Saline Water.

We believe that the engineering design and component development programs initiated by OSW, with the objective to construct a 50 million gallons per day plant, has a great deal of merit and should be supported. The southern California area and Israel are two examples of near-term applications for large-scale desalting plants of the 50–150 million gallons per day range. We can anticipate many more applications developing with increased industrialization and population expansion throughout the world. Although the cost of water from dual-purpose power and desalting plants, of the 50–150 million gallons per day range, may not be competitive with present day ground and surface water costs for Israel and southern California, they represent such a potential decrease from present day desalting costs that an engineering development program certainly appears justified. As the committee knows, the Point Loma type plant of 1–1.5 million gallons per day capacity could probably produce water at \$1–\$1.25 per 1,000 gallons, while dual purpose 50–150 million gallons per day plants, with nuclear or fossil fuel, might achieve water production costs in the 30 cent–40 cent per 1,000 gallons range. The attached figure gives the cost of water for a dual-purpose plant using nuclear energy for various plant capacity factors and cost of money. The data was developed for waterplant sizes ranging from 50 to 400 million gallons per day and is based on present day water reactors.

However, when we talk of low-cost water in these large plants, we are combining two independent factors to achieve these low figures. Specifically, we have combined the economies of scale-up of plants and the economies of dual-purpose operation. For proper evaluation, these two factors should be separately and independently analyzed.

The proposed OSW development program is primarily concerned with scale-up of flash evaporator units, which involve large pump developments, heat transfer studies, flash chamber distribution studies, tube material studies, development of large scale deaeration and vacuum equipment, and testing concrete as possible evaporator shell material. All these developments combined with component and module testing is intended to solve all the uncertain design details needed for scale-up of flash evaporators.

The dual purpose power and desalting plant represents an engineering, thermodynamic, and operating advantage over single-purpose power and waterplants, and, therefore, can be demonstrated in varying degrees of economies for small- and large-scale plants. Specifically, by having a larger heat source for dual-purpose operation than the heat source for either a single purpose power or waterplant, the unit energy charge is reduced. By hooking a waterplant onto a powerplant, there is a more efficient utilization of the available energy from the heat source. Finally, sharing the operating labor and maintenance costs between two products permits further unit cost reduction for each product.

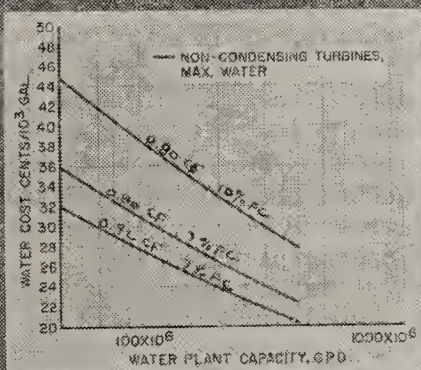
We believe valuable engineering, operating, and cost information can be gained if a smaller dual-purpose plant was operated before the start of construction of the 50 million gallons per day plant. A waterplant of 6–15 million gallons per day, combined with a powerplant and designed upon reasonable extrapolation of present day technology, will supply operating experience for

dual-purpose operation, particularly under varying water and power load variations, permit evaluation of operating costs under actual conditions, supply reliable capital cost figures based upon actual construction, and permit measurement of engineering data for application to the 50-150 million gallons per day plant. In addition, there is a near-term larger market for smaller desalting plants (below 10 million gallons per day) so that the proposed plant, if built, may have more immediate scale applications. Plants in the 6-15 million gallons per day range will probably be fossil fired and could find application in such areas as Florida Keys, Mexico, United Arab Republic, Tunisia, Pakistan, and India. With the exception of the Florida Keys, the cost of water of the smaller plant would be higher than possible alternate water schemes. However, the capital investment of the smaller plant is appreciably less than the 50 million gallons per day unit and will supply a wealth of information that can be incorporated into the large plant design to achieve economies in the large plant.

The OSW program to investigate alternate methods of desalting besides evaporation should be supported, not only to find alternate methods to produce lower cost water, but to develop techniques which may be applied for certain water conditions other than evaporation. Certainly brackish water is more economically treated by electrodialysis and possibly reverse osmosis than by evaporation. In addition, since water distribution costs are generally higher than power distribution costs, there may be applications in which smaller desalting units operating on power only, and located in various different areas, would be more economical than large centralized desalting plants with costly water distribution systems. The freezing, reverse osmosis, and electrodialysis processes may prove attractive for such an application.

However, with the proposed expanded activity in flash evaporator development and construction, one can't help drawing an analog between the nuclear reactor developments and desalting developments. With light-water reactors constructed first and continuing to improve, it has been more difficult for promising reactor concepts to show appreciable cost advantages, so that many types have been discarded. Similarly, in desalting, the flash evaporator process may well maintain its lead over other processes as improvements and refinements continue with each generation of evaporator design.

It is, therefore, important that the Office of Saline Water constantly evaluate new developments and bring those promising ones along as rapidly as possible so that they can be built for commercial application and offer an attractive economical competitor to the flash evaporator method.



WATER COSTS, PR = 12

Dr. BARON. There are two independent factors brought together in talking about low-cost water. They should be isolated. One is the economics of scale-up, from 1 million up to 50 million. The OSW program is well based and directed to find the economics of larger units.

We think the other phase of the economics, the dual-purpose aspect, should be looked at separately.

On this basis we are suggesting that we would like to see a smaller dual-purpose plant built that would demonstrate the real operating advantages of dual purpose, the actual construction cost of such a plant, and actually develop operating data from such a plant which could, indeed, be factored into the 50-million or 100-million-gallon-per-day plant.

We are thinking of sizes of 6 million to 15 million. There is nothing holy about that figure. We are thinking of something between the present 1 million and projected 50 million.

The studies done in the Florida Keys certainly show there is a real economic case for an 8- to 10-million-gallon-per-day plant right there, and it is unfortunate that certain factors prevented this plant from going ahead.

There have been discussions for such size plants in Egypt, Tunisia, Mexico, and so forth. We would like to see a dual-purpose plant of this intermediate size built and experience obtained while this component development is going on, this large-scale component development, so both of these factors can be broadened to bear on the large-scale plant.

The other point is that we certainly support the R. & D. effort on the desalting. We feel this is a necessary parallel effort to the engineering development effort of the large-scale plants.

Certainly there is need to look at possible competitive processes and there is a need for going into processes that will handle brackish water, as you have heard a great deal today.

From our own experience in the nuclear field we want to inject a word of caution. We have seen how the AEC has expended a great deal of money in developing one kind of reactor and a lesser degree on the other reactors. What has happened, a lot of promising reactor concepts have fallen by the wayside because the push that has been put on the water reactors has advanced so fast it made the others not as attractive by comparison. We think the OSW should have a very aggressive evaluation program on these other developments and bring them into larger scale as fast as possible so they can be compared on the basis of size and application.

Mr. ROGERS. You feel we have pretty well exhausted basic research in distillation processes and should move on into the production area?

Dr. BARON. There is a great deal to be done still in distillation.

Mr. ROGERS. The 15 million gallon per day plant that you speak of in these various areas, do you refer to that as a commercial operation as opposed to a research and development operation?

Dr. BARON. Yes, sir. The Florida Keys study we did showed a 10 million gallon per day plant could produce water with distribution, all the charges to the customer, initially about \$1.37 per thousand gallons.

It would decrease to something like 95 cents a thousand gallons. It would average about \$1.05 or so. People down there are paying \$1.52 a thousand gallons.

Mr. ROGERS. You feel from that size plant we would find a source for the same information for refinements in the distillation processes as we get in the modules or components and demonstration plants?

Dr. BARON. There would be one additional source.

Mr. ROGERS. We are dealing with tax money here. What I am thinking about is this: It would be nice if you could build them all and go ahead and build a 50 million gallon a day plant. What we have to do is make a choice.

Dr. BARON. I was not suggesting that the \$10 million come out of the tax money, that this would be a commercial effort and commercial plant with possibly some support from the Office of Saline Water, to the degree they thought the output of this would be of value to them, which would lead to the \$50 million.

Mr. ROGERS. Mr. Aspinall?

Mr. ASPINALL. You would follow along with the same procedure we have in the Atomic Energy Program and have some of the cost of the plant allocated to R. & D.

Dr. BARON. Absolutely.

Mr. ASPINALL. In the AEC operation the AEC does have an evaluation committee, does it not, with regard to the proposed reactors to which it wishes to give attention?

Dr. BARON. Yes, sir. Sometimes I take exception to their results; yes, sir.

Mr. ASPINALL. That is all.

Mr. ROGERS. Mr. Reinecke?

Mr. REINECKE. On these dual plants, what happens to the efficiency of the overall system? We are told there are certain savings to be made by being able to chop off the last stage or two from the turbine and use that for desalting purposes.

What happens when we get off a peak electric load? It seems we will lose some overall peak efficiency.

If the electrical load drops will we not suffer in the efficiency?

Dr. BARON. You bypass steam around the turbine and you actually do lose available energy and you are not using the plant as efficiently as you should.

Mr. ROGERS. Thank you very much, Doctor.

The next witness is Mr. W. Kenneth Davis, vice president, Bechtel Corp.

**STATEMENT OF W. KENNETH DAVIS, VICE PRESIDENT,
BECHTEL CORP.**

Mr. DAVIS. Thank you, Mr. Chairman.

I am very pleased to have a chance to appear before your committee in behalf of Bechtel Corp.

In view of the time I would like to forego trying to read any part of the statement and I would appreciate it if it could be included in the record.

Mr. ROGERS. Your statement will be included in the record the same as if read in full.

(The statement follows:)

STATEMENT OF W. KENNETH DAVIS, VICE PRESIDENT, BECHTEL CORP.

I am W. Kenneth Davis, vice president of Bechtel Corp., San Francisco. I am in charge of the scientific development department of our company which is responsible for development and advanced engineering in new fields of potential interest for our engineering and construction activities.

I was educated as a chemist and chemical engineer and spent several years in process design and development work in the petroleum refining and petrochemical fields. This was followed by a period as professor of engineering at the University of California and then by management of research and development work for a contractor to the Atomic Energy Commission. Subsequent to this I joined the staff of the AEC and served from 1955 to 1958 as the Director of the Division of Reactor Development. I joined Bechtel in 1958.

While Bechtel Corp. is a large organization, its activities are limited to providing engineering, construction, and construction management services on a professional basis. Among our principal fields of activity are powerplants—nuclear and fossil fueled, hydroelectric plants and water resources development, chemical, petrochemical, and refining processes, oil and gas pipelines, power transmission, metallurgical plants, food processing, and a variety of types of manufacturing plants. While our headquarters are in San Francisco, our work is truly worldwide. Last year, for example, we carried out projects in 30 of the States, 5 of the 10 Canadian Provinces, and in more than 30 countries overseas.

With this background it would be surprising if Bechtel had not become active in saline water conversion. Actually, Bechtel has provided desalting facilities in connection with a number of projects both in the United States and abroad over a number of years. These have included water supplies for pipeline and refinery projects in Arabia, process water for chemical plants in the United States, boiler feed water and potable water supplies for major powerplants on the west coast, etc. This includes the San Onofre Nuclear Generating Station now under construction for Southern California Edison which will have a desalting facility of about 200,000 gallons per day capacity.

However, these facilities have been of modest size and have primarily involved the specification and installation of equipment supplied by manufacturers. Several years ago we recognized that another phase in the evolution of desalination was approaching and devoted effort to acquainting ourselves with the state of development, the prospects for improvement, and to evaluating the potential of desalting on a large scale. We felt that nuclear heat sources were likely to prove advantageous for large desalting plants since these might often be in areas of high fossil fuel costs and further were convinced that the combination of water desalting with power generation would probably be attractive in many circumstances.

We concluded that the prospects for large desalting plants were favorable and of particular interest to us because of the large-scale engineering and construction involved. At the same time we recognized that considerable development and engineering application work remained to be done, even for the best-known processes; and, of course, we were aware that the Office of Saline Water was engaged in such a program. Since the subject of this hearing, bill H.R. 7092 relates to the expansion and acceleration of this program, I would like to review some of our work and comment on the significance of it with respect to requirements for further development.

Three years ago Bechtel appraised the actual cost experience of the then operating demonstration plants for the Office of Saline Water. These were the Freeport, Tex., long tube vertical multiple effect evaporation plant; the Webster, S. Dak., electrodialysis plant; and the San Diego, Calif., multistage flash evaporation plant. Our results showed that when compared on the same basis and without the experimental features, the cost of water from the San Diego plant was \$1.30 per million gallons and from the Freeport plant the cost was \$1.46 per million gallons in the 1 million gallon per day plant capacity range. A comparable cost of water for the Webster plant, but operating with its brackish water feed, was \$1.15 per million gallons in the 1 million gallons per day size range. When the MSF and LTV plants were compared at 8 million gallons per day, the costs of water were 73 cents per million gallons and 85 cents per million gallons. From these results, it was evident that the multistage flash process showed promise of significant cost reductions in larger sizes. It is noted that it is

now the process being most intensively investigated in large plant sizes for sea water conversion. These results also showed the superiority of electrodialysis over the multistage flash when brackish waters of moderate salinity are encountered.

Following this work, Bechtel Corp. performed a conceptual design study of very large multistage flash desalination plants for the Office of Saline Water. We prepared designs of 50 and 150 million gallons per day plants, estimated their costs, and determined the cost of water from single-purpose waterplants, and dual-purpose plants producing both power and water. The results of this study have been used widely. They were the basis of the water conversion costs reported in the Office of Science and Technology's landmark report on the potential of nuclear energy for desalination.

One result of this study was that combination desalting and powerplants were advantageous, at least under the conditions assumed in the study, in reducing the total costs of power and water. It was evident that further work needed to be done to investigate the characteristics of such possible combined operations on actual systems as compared with the idealized conditions postulated in the study.

Another important result was to show that large-size plants could desalt sea water at costs which might be acceptable for large-scale use, costs of the order of 35 to 40 cents per 1,000 gallons.

During this study we developed a computer program which was used to determine the optimum plant design to produce water at the lowest cost. This computer program and variations of it are now widely used for conceptual designs of flash evaporation plants. The Office of Saline Water recently requested that we provide copies of our program to nearly 20 of their contractors, who are engaged in conceptual studies of plants of 50 million gallons per day size.

Also in this study, we recommended that concrete was potentially an economic material for evaporator vessels and we are pleased to see that the Office of Saline Water is now carrying out a program to develop and test concrete vessels.

The use of concrete for evaporator vessels looked sufficiently promising that we undertook an in-house study comparing concrete with steel to determine the savings which could be made in small- and medium-size plants. We found that plants as small as 1 million gallons per day could be built cheaper with concrete because it is ideally suited for on-site construction and costs are reduced by casting repetitive modules. Such construction may be of particular importance abroad.

Our study brought out several questions which must be answered before concrete can be used. What are the most suitable coatings to render concrete practically airtight to prevent leakage through the vessels? How can construction joints and seals be made to provide a leaktight structure? At what temperatures must the vessel be lined to prevent attack and what materials should be used?

We hope the present OSW tests designed to answer these questions will show how concrete can be used in sea water conversion evaporators.

Recognizing the inherent potential merit of large size nuclear power reactor plants as a source of inexpensive thermal energy for desalination plants, the U.S. Atomic Energy Commission in 1963 awarded a contract to Bechtel to assemble cost data for reactor powerplants ranging in size from 1,500 megawatts thermal to 25,000 megawatts thermal. The types of reactors included light water moderated and cooled; heavy water moderated, organic cooled; graphite moderated, light water cooled; and fast breeder reactors. Designs representative of both current technology and advanced concepts were included. The AEC Division of Reactor Development, and the AEC Hanford, Savannah River and Oak Ridge Operations Offices or their subcontractors all supplied cost information for this study.

The results of this work should furnish guidance for reactor development planning. Of immediate application, however, the results formed the basis for the estimation of the steam costs for the Office of Science and Technology's Interagency Task Group assessment of large nuclear powered desalination plants.

I would also like to mention briefly another important project we are presently doing even though it is too early to report any results. This is the desalting plant study for the Metropolitan Water District of Southern California which is partially supported by the Office of Saline Water and the Atomic Energy Commission.

The objective of the project is to determine the engineering and economic feasibility and provide a preliminary design of a combination power and desalting

plant using a nuclear energy source. This combination plant shall be suitable for operation by the district by the year 1970. The study includes an analysis of combination plants with outputs of 50 to 150 million gallons of water per day and 150,000 to 750,000 kilowatts of electric power.

We believe the results of this study will make a significant contribution by determining, on a realistic engineering basis, the immediate prospects of desalted water as an added source of water supply for southern California. This study will furnish an opportunity to examine in detail the important practical aspects of combined operation, water storage, transmission and blending, and other aspects of a large actual system.

I would now like to comment on areas of general research and development in desalting technology wherein we feel that useful results obtained could make further advances in the art.

In the evaporation processes, it is probably accurate to speculate that favorable results in R. & D. would probably provide percentage reductions in cost desalinated water but probably not reduce cost by a large factor. Areas needing work include: (1) better definition of design parameters for orifice and baffle configuration, (2) better utilization of pressure differences, (3) better and less expensive condenser tubing materials, (4) improved pumps, (5) low-cost scale prevention and deaeration techniques for cool sea water.

For the single-purpose water-only evaporation plants where high-temperature operation with associated gains in thermal efficiency may be desirable, we need cheaper heating sources, improvements in process design, improved materials for the higher temperatures, and low-cost scale prevention techniques.

With regard to the nonevaporative processes and considering fruitful areas for development, it is noted as previously pointed out, that the electrodialysis process is generally preferred today in the brackish water areas for municipal water desalting. Reverse osmosis is still promising, but we need to reduce costs and improve membrane lifetimes.

It is our conviction that more attention should be devoted to ascertaining the requirements for water desalting—market surveys, if you will. Further, such work is needed to clarify the potential demand for water desalting facilities in the various size ranges and thus the emphasis in the development program. Those who have attempted such surveys will agree that this is a complex and difficult task due to the many factors involved. Nevertheless, it seems essential.

It should be remarked that there are few areas where the costs have as little relationship to the price as in the case of water supplies. This is particularly frustrating to engineers who are accustomed to a close cost-price relationship. There are many reasons for this situation, most of them quite valid. However, the problem in trying to evaluate the potential of a new technology in such a situation on the basis of cost is not an easy one.

It must be noted also that there is a considerable tendency to consider average prices and costs when the incremental costs of adding to or even replacing existing water supply systems may be much higher than reflected in averages.

In short, the question of ascertaining the potential demand for desalted water as a function of price and quantity must be approached with a great deal of good sense and understanding of the many practical circumstances involved. It should also be recognized that additional water supplies are usually only a part of an overall situation involving water management, waste disposal and pollution control, power, etc. Effective application of water desalting technology must take these aspects into account.

Thus, the program must aim in one direction at the practical demonstration and application of the emerging technology in the real world and in the other at identifying and developing new processes which can lead to future significant cost reductions. Such a program should be carried out with full cooperation of the future users as well as of the manufacturers and engineer/constructors who will furnish the plants.

While the foregoing has necessarily been rather general, I believe it supports our conviction that additional development and application work as well as more research is needed in the field of saline water conversion, and that we are thus in support of the objectives of H.R. 7092. "A bill to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes." The extension in time and authorized funds appears appropriate to us.

This completes my statement and I would be happy to answer any questions.

Mr. Davis. I am a vice president of Bechtel Corp. and in charge of the research and development work.

We have built over the years a good many small water desalting plants and we have during the past several years done a considerable amount of work for the Office of Saline Water and for other private plants and some in-house studies.

Rather than go into these in any detail I think I should point out probably the most significant project we are working on, which is being supported by the Office of Saline Water, the Atomic Energy Commission, and the metropolitan water district, is the study we are now making for the metropolitan water district.

I would like to state our position in general support of the subject legislation, H.R. 7092, and to perhaps make a few comments on the need in my mind for development work as well as for large-scale facilities.

There have been a number of comments here about the necessity of going ahead and actually constructing large-scale plants of the type that are now fairly well developed, and this is primarily the multistage flash.

There has been some thought here, I gathered, that if one is in a position to do this perhaps there is not a need to proceed, even with further research and development work on this type of process. I think I would be inclined to agree if someone said, "Is there much area for fundamental research in the multistage process?" I think there is really not a great deal of what you might call basic or fundamental research. There is, however, a great deal of applied development, applied engineering, and so on, which needs to go ahead both in connection with any project to build a large-scale multistage flash plant and also to go ahead in order to support later construction of even better plants.

One item that I mentioned in the written testimony, which I think is a good example, is that in some of our studies we have concluded that the use of concrete chambers to house the multistage flash tubes and the water coolers would be considerably cheaper than steel.

One cannot say this makes a big difference in the overall cost. However, on a plant the size of the one we are considering for the metropolitan water district it would make a difference in cost of several million dollars.

One is not able to proceed today with the design of a plant based on the use of concrete, which is presumably a fairly well understood material, but there are many practical problems of how to protect the concrete against corrosion by salt water and salt water high temperatures, how to provide construction joints, concrete wall which does not leak too much to sustain the low pressures required, and things of this sort. There is a development program which needs to be done and things which need to be found out.

There are matters associated with the life of such a plant which need to be explored before anyone is in a position to build a plant which they can say confidently will last 25 or 30 years.

I think this is an example of one of the areas of activity that needs to be carried out on a development basis. You are trying to develop an engineering technique.

At the same time there are many variations even of the so-called multistage flash processes. The ones we are looking at today in con-

nection with the so-called dual-purpose plants, such as will produce power and water, will operate at fairly low temperatures. On the other hand, for those situations, and there may be many of them, where it is not desirable to combine power and water production, then one has an incentive to go to the highest possible temperatures in the water plant, and one then is right up against materials problems which may limit the development of the multistage flash in that direction even though one may be able to go ahead with large-scale plants operating at lower temperatures.

I think these are the kinds of things that are basically involved in the need here for a program which proceeds with research and development and at the same time has in it, as Mr. Aspinall has pointed out, some of the actual design and construction experience of large-scale plants as has been done in the atomic energy program.

I think there is one other aspect here, too, which again relates to the kinds of problems that have begun to become apparent in the Metropolitan Water District study, and that is it is very fine to look at these various plants on the basis of a theoretical study and to assume all of the conditions are ideal.

When one has the problem of finding a site for a plant, having to find out where to transmit the water, how to mix it with the other water, where to transmit the power, how to run the two systems jointly, it gets into the really practical problems, some of which were mentioned by Congressman Reinecke.

It optimizes the picture again and the picture begins to look different. New problems appear and new solutions have to be found. Nothing is unsolvable, and nothing is terribly difficult, but it is something that has to be done on a really practical engineering basis.

Our conclusion is that we feel an expanded program, with emphasis in some of these areas, such as in the area of reverse osmosis, combined with a program of making engineering applications, is a sound one and it is needed in the saline water program.

I think with those few comments I would like to conclude and answer any questions you might have.

Mr. ROGERS. Thank you, Mr. Davis.

Mr. ASPINALL. Mr. Davis, do you have any present contracts with the Office of Saline Water?

Mr. DAVIS. We have one directly, and the one I mentioned, more or less indirectly, Metropolitan Water District.

Mr. ASPINALL. Can you guess at the amount of money you have received?

Mr. DAVIS. Exclusive of the MWD contract I would guess about \$150,000, something on that order.

Mr. ASPINALL. The plant that you talked about in the statement, the nuclear generating station, is the one being constructed where?

Mr. DAVIS. That is under construction. The sphere is complete. Equipment installation is proceeding.

Mr. ASPINALL. When do you expect to have that ready?

Mr. DAVIS. I have forgotten the exact date, but a little over a year from now.

Mr. ASPINALL. This will be a dual-purpose plant?

Mr. DAVIS. This will be primarily a powerplant. As I pointed out in the testimony, there is provision in the plant to make the water

necessary for the boiler, and so on, and this has been done with most of the powerplants on the Pacific coast.

Mr. ASPINALL. You favor at this time the additional authority that is being requested by the Office of Saline Water and for the program they have presented here?

Mr. DAVIS. This is certainly my position, sir.

Mr. ROGERS. Mr. Reinecke?

Mr. REINECKE. I have no questions.

Mr. ROGERS. Do you feel that in the distillation processes we have pretty well come to a position where we need to move on into production rather than continuing a great deal of research and development?

Mr. DAVIS. I think there is a need to get on with building some large-scale units of the sort that are now quite feasible from a technical point of view.

Mr. ROGERS. What size would that be?

Mr. DAVIS. Anywhere up to those we are studying now, a plant of up to 150 million gallons a day. This appears to be technically quite feasible and presents no large problems.

However, I would not like to see the fact that this can be done as any kind of a justification for dropping the associated development work which is needed to produce either better large plants or other types of large plants which, as I pointed out, might be high-temperature plants or in some way differ from those which can be built fairly readily today.

Mr. ROGERS. Couldn't that type of research be carried on in modules in connection with the size plant you are talking about being built.

Mr. DAVIS. It could be carried out on modules. When one is building a very large plant as a production plant I do not think it is too good an idea to try to put into that plant experimental features which if they did not work might interfere with the operation of the plant.

You do not want to jeopardize the plant that may cost a couple hundred million dollars by putting an experimental feature in it. This is a matter of degree but I would not like to see it an experimental plant.

Mr. ROGERS. You feel more attention should be given to the reverse osmosis process?

Mr. DAVIS. This in my mind is an extremely interesting and straightforward way, aside from distillation, of accomplishing the desired result. Whether it can be economically a large scale is still a question. It is worth intensive effort.

Mr. ROGERS. Thank you very much, Mr. Davis.

The next witness will be Mr. R. W. Akerlow, manager, special projects division, and Mr. C. G. Rogers, project manager for the OSW Freeport demonstration plant, representing the Stearns-Roger Corp.

STATEMENT OF R. W. AKERLOW, MANAGER, SPECIAL PROJECTS DIVISION, STEARNS-ROGER CORP.

Mr. AKERLOW. I will brief this out.

Mr. ROGERS. Without objection this statement will be inserted in the record in full, Mr. Akerlow.

(The statement follows:)

STATEMENT OF R. W. AKERLOW, MANAGER, SPECIAL PROJECTS, STEARNS-ROGER CORP.

Stearns-Roger Corp. of Denver, Colo., is an engineering-construction firm of over 80 years' experience in serving both Government and industry. Our primary field is application engineering, which strives for optimum combinations of engineering know-how to accomplish the engineering tasks of our customers. We are currently operating the Freeport demonstration plant for the Office of Saline Water. In this capacity, we have been deeply involved in the technical and mechanical development of the multiple effect, falling film evaporative process for desalting sea water.

Stearns-Roger Corp. is pleased to present their views relating to points raised in the committee's letter to conduct a hearing relative to:

(1) The respective responsibilities of the Federal Government and private industry to accomplish research and development in recovery of fresh water from saline waters,

(2) The direction the program should take in the future.

At present there are several sea water demonstration programs, and many research efforts directed toward achieving the economic desalination of water. Pending a technology breakthrough, it is our opinion that the evaporative processes will continue to be the most widely applied in desalting plants. However, the limits of evaporative processes need to be extended to become more efficient, and the need exists for alternative processes which can be economically applied for brackish water situations. A real "breakthrough" will not be achieved easily. Therefore, the broad scope of the present program needs to be continued or even expanded if a breakthrough is to be found, and it will develop the "arsenal" of know-how to best approach each local situation as it develops.

The role of the Government is to give the necessary impetus to a program of research that private industry has been unable to provide because of the present economics of water. Water has such a low unit value that it falls into the category of "necessary to operate" instead of "salable product" as far as normal industry is concerned. Therefore, its availability has been a determining factor in the location of industrial facilities.

Industrial research on the private level has not been necessary, because the actual shortage areas are few in number in the United States at present. This present availability of water-rich locations is decreasing. Methods of providing water for the more arid regions where a brackish supply abounds could be a definite boon to industrial expansion, and thus develop areas of chronic economic depression, where water is in short supply.

The Government has been providing this emphasis through the Saline Water Act. Prior to 1961 desalting was accomplished on a laboratory or pilot-making scale, or in small marine evaporators. Potable water from desalting was expensive. The action of the Congress in establishing production-size development plants was instrumental in the rapid demonstration that the cost of desalting water could become attractive to industry as well as the individual consumer.

The Freeport plant is an example of the progress which was made. The continuous testing of the results of research under controlled conditions, by an unbiased operator, has produced results. Materials, individual unit operations modules, and the overall process have been improved, resulting in an increasing ability to combine the right things into a lower cost plant, while maintaining or improving reliability and efficiency. Private industry could not at present justify the broad approach which is necessary to advance the state of the art. By supporting a continuing program of research and development, costs have continued to be lowered. This has resulted from improvements in—

(a) Reliability—More production from more on stream time.

(b) Efficiency—Process improvements to decrease energy requirements.

(c) Mechanical design—The simplification of equipment and decreased capital investment requirements for a given capacity.

It seems to us that the Government and industry both hold responsibility for continuing the present program. Industry is accepting the burden of private research and development in areas of specific types of equipment and processes. When a particular opportunity arises wherein byproduct recovery can be expected, we would suggest cooperative research or research cost sharing on the part of industry and Government.

Outside the United States, in many areas of the world, the need for water is immediate. The advances already made and the ones to come provide a most beneficial form of technical assistance to other nations, and can be a real factor in promoting the ability of American industry to successfully compete in the export of complex industrial facilities and equipment as well as provide a humanitarian service to other nations.

The role of industry is secondary, in our opinion, as far as the very large size nuclear powered electricity-water combination plants are concerned. The need for these facilities is regional and transcends the requirements of any one segment of industry except the utilities. Cooperation has already been offered in this effort, by the utilities themselves, and the larger companies who have accepted the "conceptual design contracts" for these large facilities.

True multiple-purpose complexes seem to offer a fruitful area of industry-Government cooperation. Government should take the lead in recovery of the many valuable chemicals and elements present in sea water. Industry should consider shouldering a major share of costs if there are good indications that economic recovery is possible.

The Government can well afford to promote this type of development which will eventually result in the economic growth attending the establishment of a facility that would produce, for example, electric power, potable water, chlorine and caustic soda, salt, magnesium and/or magnesia, bromine, etc., all from its energy source and the sea. This operation could feed these basics to the manufacturers of intermediate and final products of almost infinite variety.

We are recommending that the general course of the Government's program be inclined to remain broad in scope. Large-size plants should be developed with care to properly evaluate the energy source and the distribution of costs. The larger utility companies will have to be considered in order to economically dispose of the power and water to the consumer and these share in development costs.

Dual-purpose water and powerplants using fossil fuels are a definite possibility for municipalities.

The total-energy concept of waste heat recovery is very adaptable to the 10 million-gallon-per-day waterplant, where fossil-fueled engines are the prime movers for generators. Demonstration of this might be in order and will undoubtedly receive considerable support from industry.

We would like to conclude our comments by outlining the function which the Freeport Demonstration Plant can provide in the future. The record to date has been described in detail in the Summary of Performance report of February 19, 1965, prepared by Stearns-Roger. The plant has demonstrated the highest thermal efficiency in the free world, as well as reliable operation. Recent advances have indicated that very significant improvements to this already high efficiency can be achieved, by modifications at nominal investment costs. Softening of the sea water feed by ion exchange and/or chemical fertilizer recovery methods will allow operations at higher temperatures than ever before attempted on demonstration plant size to produce lower cost product.

Removal of silt and other objectionable materials from the feed is underway. Chemical recovery from the effluent can be attempted. Improved instrumentation which is presently being installed will allow this plant to provide pilot plant quality data on the production size units installed. All of this will provide a source of technology that will be invaluable to designers of future plants, while demonstrating the many faceted potential of this already proven desalting process.

Thank you.

Mr. ROGERS. Thank you very much, Mr. Akerlow.

Mr. Spinall?

Mr. ASPINALL. I have a question relative to the future of Freeport. How long can Freeport continue to operate under its present authorization?

Witness C. G. ROGERS. Our contract with the Office of Saline Water can be extended 5 years, I believe, under the present contract.

Mr. ASPINALL. Until 1972?

Mr. AKERLOW. We have a 1-year extension at the moment, sir.

Mr. ASPINALL. We gave authority for a definite period of time. I may be mistaken. I thought that time was supposed to run out next year. We will find out.

Anyway, you have answered my question as to what you think and as to what use can be made of it effectively in the future.

How much money has Stearns-Roger received from the Office of Saline Water throughout the years?

Witness C. G. ROGERS. For the operation of the Freeport plant we have received approximately \$1 million in 4 years.

Mr. ASPINALL. How many other contracts do you have?

Witness C. G. ROGERS. No other contracts.

Mr. ASPINALL. In your first paragraph you use the phrase "falling film evaporative processes." I wish you would explain that in terminology we have been using.

Witness C. G. ROGERS. The falling film process takes steam from a heat source and is fed into the outside of the heat exchange unit and boils the sea water that is falling through these tubes, which furnishes steam for the following unit.

Mr. ASPINALL. In other words, this is a distillation process?

Witness C. G. ROGERS. This is a distillation process.

Mr. AKERLOW. The problem on this plant at the time that Gitmo was being considered was that we had not really had a breakthrough on the scaling of this system. It has been only in the last about 7 or 8 months we have operated scale free now up to temperatures of 270°.

Mr. ASPINALL. I don't think the cost of producing water per thousand gallons would be important, but what is the percentage you have lowered the cost in the production of water because of this breakthrough which you referred to, as well as other improvements from the time you started?

Witness C. G. ROGERS. We have actually been asked by the Office of Saline Water to maintain a million gallons of production at this plant, and we, in turn, have reduced the heat transfer service in the evaporators themselves by 30 percent. The Office of Saline Water has, through their accounting methods, put out some statements that if we were able to use the full heat transfer surface that this would be comparable to 95 cents per thousand gallons of water.

When we started off the first year's operation that water cost around \$1.62.

Mr. ASPINALL. In other words, reduced it somewhere in the neighborhood of 70 percent?

Mr. AKERLOW. Each unit on the evaporator units as we have them there, the way they were given to us, have a pump at the bottom of each unit and it transfers the product water.

Rather than put it in all new pumps we took out surface and in that way we judged the efficiency on the basis we reduced the investment, you might say, and in that way reduced the cost of the overall experi-

mental program to a reasonable figure. We are finding out things you need to learn on that basis.

Mr. ASPINALL. Let me ask a personal question, because I know of the great benefits that you have given the mining industry. Do you consider that this particular breakthrough to which you made reference is the product of the Stearns-Rogers operation of this plant?

Mr. AKERLOW. We like to think so, sir.

Mr. ASPINALL. I will not quarrel with you.

Mr. Reinecke?

Mr. REINECKE. You mention the total energy concept on the past page.

Mr. AKERLOW. You will see recently higher developments of a gas turbine as a total energy. We speak of using total energy in which the exhaust gases from gas turbine are fed into a waste heat boiler and that in turn feeds the salt water plant to make fresh water.

At the present time there are many of these units going in throughout the country. We have been involved in some where they use the waste gas as a heating boiler to make refrigeration in the summer. It is a new development.

In some of the islands off the coast of California we have developed estimates for real estate companies which might want to develop that to get water and power at the same time.

Mr. ROGERS. Thank you very much.

Next is Mr. Harold Hay, consultant on solar distillation.

STATEMENT OF HAROLD HAY, CONSULTANT ON SOLAR DISTILLATION

Mr. HAY. Mr. Chairman and members of the committee, may I anticipate Mr. Aspinall's question and give him an unusual answer. I never have had a nickel from the Office of Saline Water.

May I further say that I am including two suggestions in my testimony for consideration in the legislation proposals and therefore with your kind indulgence, I would like to take a little more time than I otherwise would at this hour.

Mr. Chairman, members of the committee, following procedure, I, Harold Robert Hay, identify myself as a consultant and inventor who has developed—from a stage of theory to commercial sales—a wood preservative now used throughout the world; who has had issued patents on a water purification process also used throughout the world but not dealing with water desalination; and who has had numerous claims allowed on a yet unissued patent dealing specifically with desalination by solar distillation. I have worked for private industry, for one of our largest research institutes, for the United Nations, and for the U.S. Government in several categories including that of consultant. In all of these respective employments I have been sent abroad. I have lived in Sweden, Mexico, Venezuela, Colombia, and, longest of all, in India.

Mr. Chairman, desalination of sea water is being discussed here as if it were something new and the hope of the future. Nuclear distillation is mentioned as a most promising process. The main emphasis is on millions or hundreds of millions of gallons per day, and on how low the cost will be. To gain a better perspective, I wish we would

recognize this amount of water as negligible, the costs as exorbitant, and the nuclear process itself as ancient. These are connective facts when one reflects that the nuclear process preceded man by billions of years, and that it is the basis of all rainfall and hence of all fresh water on this earth. I refer, of course, to solar distillation.

In 1870, some New York inventors received United States Letters Patent No. 102,633 for a solar still which they said "was based on well-known physical laws." And they invented so well that nearly 100 years later, some university research workers developed the same design and planned to patent it. Mr. Chairman, in 1872 a solar still was built in Chile and was used successfully for many years. Stills of this identical basic design are now being used in various parts of the world—but they get little attention in the United States.

The unfortunate fact is that since 1872 practically nothing was added to solar distillation technology until military needs called for portable stills to be used by individuals at sea. This research stimulus died. Nothing more was done until 1953 when the Office of Saline Water contracted for some literature reviews with evaluation which later became the Office's Research and Development Progress Report Nos. 4 and 5. In the last 10 years, the Office pursued the solar process: first, at a commendable rate; recently, however, there was nearly total neglect of the process. The sun rises and sets and continues to distill water from the sea. But one should not expect scientific research to be turned on and off with the water of life nonetheless supplied now and during the future water shortage, which is the concern of this committee.

One gains the impression that initial enthusiasm for solar stills was based on their simplicity and free energy. This, unquestionably, led to oversimplification of thinking which once was properly defined as "the evil of small minds." In the main, administrators selected, or depended, upon uncreative engineers and asked little more than to study solar stills, improve them, lower their cost, and get them into production. No other process was at a stage where it could be so oversimplified. The consultant collected fees, grants were made to research institutes which were barren, pilot plants were installed, data were collected. When possibilities for rehashing old engineering ideas ran out, funds were given to feed previous data to computers. But at the end of it all, results were essentially no better than in 1872.

The administrative reaction, apparently, was that too many desalination processes were being studied and this one of solar distillation should be dropped on the justification that the possibility of producing millions of gallons of water per day for cities was remote—too much land would be required—and previous failures were too embarrassing to be discussed further. The situation developed that it became impossible, at least for an individual inventor, to get a complete and fair hearing for new ideas on solar still designs. Many points were disregarded or wrongly evaluated such as the following:

1. The United States, today has 65,000 ranches in States with occasional or permanent water shortage. Thousands of new ranches could be established in areas of marginal supply if an assurance could be given that cheap desalination means could provide a few thousand gallons of water per day for cattle during the driest part of the year. The processes which have been discussed in this hearing are totally

uneconomic for bringing these scattered ranch possibilities into existence.

2. In the West, even in small cities, the cost of land is not prohibitive for solar stills.

3. Modern solar still design is increasingly based on plastics—the price of which drops every year and the properties and fabrication of which are being improved every year.

4. New, creative thinking on solar stills is being done abroad and in this country—without support from the Office of Saline Water—which gives promise of a breakthrough on miniaturizing the natural desalination process.

In Australia, Israel, the Barbados, and north Africa major research projects are underway. The State of California and Mexican organizations are busy with solar stills on a small scale. The State of Arizona not only has solar still studies underway but is internationally regarded as a center for solar energy uses. In Greece and Spain, the Governments are planning to install stills on a broad basis and are seeking leadership from the United States.

Perhaps a hundred million individuals whom we Americans consider poor and dirty have inadequate water to be other than they are. Some persons do not have for 1 day's supply the amount we use to shave with. In some localities, the Government must pay nine-tenths of the water bill—the people cannot pay more than one-tenth of the high cost. The United Nations in 1964, published a book-sized study, titled "Water Desalination in Developing Countries." This reports:

Per capita water consumption in certain areas is so small that it is barely adequate to meet the drinking requirements of the inhabitants.

I should like to read briefly from the 1963 publication of the National Research Council, titled "Desalination Research and the Water Problem":

As was emphasized by the President [John F. Kennedy] * * * the opportunity of providing developing countries in arid regions with saline water conversion facilities as part of our foreign aid program is most appealing. Supplies of good water can mean more, and perhaps cost less, than any other things we might do for peoples whose living standards are depressed by lack of water. A recent congressional report comments as follows: "To the United States, which has a vital stake in seeking their goodwill and in cementing pro-Western attitudes of peoples in underdeveloped lands, the means for providing the know-how and equipment for the production of pure water could be a telling item in international relations—to say nothing of economic factors." * * * Cheap solar stills will be more appropriate than large units requiring a great deal of electric power, the reverse of the situation in this country.

President Johnson has likewise recognized the significance of desalination as an instrument of international relations. Yet, the Office of Saline Water is isolated from consideration of foreign relations by being in our Department of the Interior. Therefore, I should like to recommend to this committee that provision be made to have the Office of International Scientific and Technological Affairs of the Department of State represented on the Advisory Committee which the Director of the Office of Saline Water is proposing to establish.

It seems ironic to contemplate that if one American were known to be lost on a desert, whether it be in our West or in a foreign land, a search would be started, planes called out, and the facilities of hospitals made available so that he might, perhaps, survive the ravages of

thirst. This is commendable care of that individual. But, today, it is seemingly impossible to get that amount of financial backing from the prime Government source to investigate new solar still designs which could benefit millions of individuals.

Recently, the Church World Service installed a solar still in Greece and discussed with the Government of Greece the possibility of building units on 150 islands. The other processes discussed at this hearing would, as in the case of our western rancher, be totally uneconomic. The first still in Greece was built according to plans from one of our largest corporations, which had collaborated with the Office of Saline Water. Yet, that still has encountered problems and I am now advised that it is being replaced by a still of my design—one which uses but one of several new principles I have developed without assistance from any source.

This causes me to comment that creativity is the essence of many breakthroughs. Large corporations, large research institutes, and large Government agencies are not the sources of creativity though they may be the best means for its fulfillment. Creativity surges from the individual, and it can just as easily, or perhaps more easily, come from the creative individual who is not within large organizations. The individual does not need, and perhaps should not have, much funds if he is to confine his creativity to the economic level of the thirsty.

May I suggest that this committee consider the reestablishment of support for solar distillation processes. Today, the door is shut on new ideas. If as little as 5 percent or even 1 percent of funds being proposed for desalination were specifically earmarked for solar designs, with the big five processes getting the rest, there would be sound encouragement for new and creative thinking in the solar energy area. I would propose a restriction, however, that this precious drop of sustaining funds should not be used for 1872 designs; and that new ideas should not be evaluated by those whose previous Government grants have proved unproductive. Rather, I would propose that creativity be sought out and given an open door even though it be outside the large research organizations which long ago had to give up their once-popular concept of collective creativity by a brain trust.

It is not true that creativity, research, and invention, today, are beyond the means of the individual in all fields; it is not true that solar distillation is an overworked, washed-out area of no promise; it is not true that the United States should think solely in terms of desalination plants with capacities of at least millions of gallons per day. In our West, we have many areas where water supply is marginal and where an additional bit of fresh water for emergency purposes, such as could be supplied by a solar still, could make all the difference.

The poor we shall always have with us—and they need water. The sun we shall always have with us—and it takes water away. But with the help of this committee, and with some brain stretching by some creative individuals, the sun can be made to give back enough of that water to make this a better world for many. Solar stills must be made cheaper and better. Research on solar stills must continue—though it recently has had hard going. If this committee will help by earmarking a very small portion of the funds for the desalination program to solar distillation, there is the certainty of shortening the time required for economic desalination to benefit those ranchers and,

as well, to benefit those poor of many lands whose only hope lies in the first and biggest desalination process being brought under control.

Mr. ASPINALL. Thank you, Mr. Hay.

Of course, this paper of yours is not new to me, especially. I have often wondered why more emphasis has not been placed on this particular process which I suppose has its beginning back further than desalination.

Have you recently made application to the Office of Saline Water, or made a request for some research money to help finance some of your endeavors?

Mr. HAY. Two and a half years ago, or so, I called on the Office of Saline Water to discuss my ideas soon after I had conceived them. At that time I received the impression that, administratively, additional research on solar distillation would be discouraged.

I was kindly referred to people who had worked in that area previously—that is, who had supervised contracts and things of this kind—and they were very helpful to me. I am appreciative of the work the Office has put out. It has been helpful to me in my thinking and design.

Then I left the country for a period and only recently I again went back to ask whether or not the policy had been changed.

I was advised that the policy had not been changed, that there is no encouragement for research work in the area of solar distillation, and this, it was clear, would be without regard to any new ideas brought in.

I feel that this is hardly a research attitude. This is hardly receptivity to meet the needs of people who cannot afford complicated processes, who do not need hundreds of millions of gallons, but who need 10 gallons or 100 gallons or 5,000 gallons.

Mr. ASPINALL. What you are talking about is providing people with the same kind of service that the reverse osmosis proponents offer. You are thinking of small amounts of water, 10 say 50 gallons of water a day, per family, at a reasonable cost. I suppose that is what you have in mind.

Have you any idea what the latest cost of a 25-gallon-per-day-solar process would be for a rancher in the West or on the desert?

Mr. HAY. Mr. Chairman, I can give you a few figures which I cannot vouch for, having just returned to the United States, and taken up this subject. My impression is that the early solar stills were priced at \$1 a square foot, and with the cost of water being \$1.60 a thousand gallons.

The latest report from the Office of Saline Water indicates the cost of a still at 85 cents a square foot if minimum-wage labor is used. I am quite confident that my stills will cost closer to 50 cents, perhaps as low as 30 cents if built in foreign lands, and this is not my optimism, but this is derived from a statement which has come to me indirectly as an indication from the consulting engineer who is installing the still in Greece. He expects the previous cost to be lowered 30 percent to 50 percent by my particular process.

Mr. ASPINALL. How much would that cost per gallon?

Mr. HAY. Whereas previous costs may have been of the order of \$1.60 per 1,000 gallons, I would now estimate this under \$1.

Mr. ASPINALL. With regard to the stills which have been constructed today, have they been on the magnitude of 1,000 gallons per day?

Mr. HAY. The solar still built in Greece is approximately 5,000 gallons a day, sir.

Mr. ASPINALL. Thank you for your statement. You have quite a number of recommendations in here which the committee will take under consideration.

The gentleman from California.

Mr. REINECKE. A very refreshing statement. Again, quantitatively you are talking in terms of 30 cents to 50 cents per square foot construction cost. What is the yield per square foot?

Mr. HAY. This will depend. I have a number of different processes. The simple distillation process which is being studied in Greece, the one-stage process, will probably not vary from the previous practice of six-tenths of a pound per square foot area.

Mr. REINECKE. Per day?

Mr. HAY. Per day. The multiple-effect stills which come within my patents and designs could considerably increase this and consequently reduce land usage. They will have higher construction costs. The economics of this is yet to be worked out. I don't know quite what costs will be.

Mr. REINECKE. Thank you.

Mr. ASPINALL. Thank you very much, Mr. Hay.

The chairman has in his possession a statement by Dr. Myron Tribus, Thayer School of Engineering, Dartmouth College, New Hampshire. The statement was presented and prepared for the other body, but I think it is of sufficient value that it should be placed in the record here.

Without objection, it is so ordered.

(The statement follows:)

STATEMENT BY DR. MYRON TRIBUS, DEAN, THAYER SCHOOL OF ENGINEERING, DARTMOUTH COLLEGE, HANOVER, N.H.

Mr. Chairman, permit me to begin by expressing to you and the other members of the committee my appreciation for being invited to testify concerning the matter before us this morning.

I am the dean of the Thayer School of Engineering at Dartmouth College. I have spent more than 23 years in engineering, as a professor and as a consulting engineer. My clients have included various branches of the Government, the North Atlantic Treaty Organization, several departments of the General Electric Co., and other commercial enterprises. My publications and textbooks in engineering are in use in many countries. My interest in sea water conversion was sponsored in 1949, 3 years before there was an Office of Saline Water. From 1954 until 1961 my research in saline water conversion was sponsored by the State of California. In 1961 I left California for New Hampshire. Since that time my work has not been sponsored either by the State of California or the Office of Saline Water.

The central subject of my inquiries has been the economic optimization of the various methods for making fresh water from the sea. My students and I have studied each method that has been proposed in order to see in what manner the methods might be improved and just what the ultimate potential of each method might be. The results of some of our work are contained in the several documents you see in this pile beside me. Based on these studies, which now span 15 years, I have come to several conclusions regarding the Federal program in desalination.

In my testimony this morning I will make three points:

- (a) The emphasis of the Federal program has been badly misplaced;
- (b) There are very good reasons why the program has not heretofore been properly directed; and
- (c) There are some specific things which the Congress ought to do to put the program on the right track.

The original legislation establishing the program in saline water conversion in 1952, and every subsequent piece of legislation, have left no doubt concerning the intentions of the Congress. Every piece of legislation contains the phrase "low cost". The central issue in this program is the reduction of the cost of water produced from saline sources. In this connection the program differs markedly from most other Federal research and development programs. In the space race and in defense the objective is to accomplish a certain new and often hazardous mission, one in which cost is not the primary consideration. In no other American enterprise has the responsibility for reducing costs been located so centrally in an agency of the Federal Government. Despite this difference, the activities, programs, and procedures of the Federal Office of Saline Water have been organized more or less to resemble activities of the Federal programs which have a much different objective. In order to make this point explicit, I should like to describe to you just one result from our work. The technical material I am about to present will be brief. It sets the stage for what I have to say later on.

Every method for making fresh water from saline water must contain at least the following two essential elements:

(a) A special surface at which the fresh water is separated from the saline water. It costs money to create and maintain such a surface. The expense of this surface shows up as a capital investment and, to a lesser degree, as an operating cost;

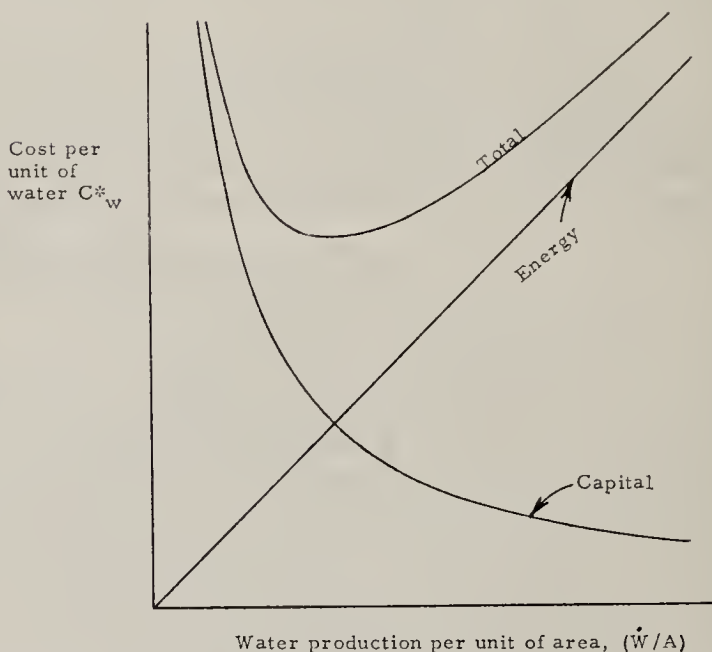
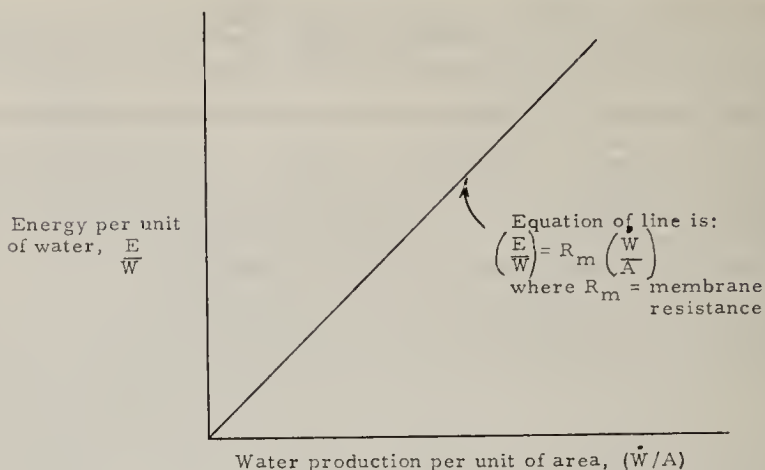
(b) A source of energy to make the process "go". This source of energy may be electricity, coal, oil, or perhaps even a special "collector" for solar energy. Except in the case of solar energy, the cost of the input energy appears as an operating expense.

An engineer who aspires to make fresh water from saline water at the lowest possible cost must combine these elements in such a way that the balance between capital cost and operating cost is most favorable.

Every scheme for making fresh water from saline waters will have a characteristic behavior for its separating surfaces. The accompanying figure 1, which refers to reverse osmosis, shows what I mean. As you can see on the figure, the more rapidly you try to process water through the separatory surface, the more energy you must expend for each unit of fresh water produced. A graph like this can be constructed for every process for making fresh water from saline water. It represents a general rule which occurs in all engineering equipment. For example, the faster you drive your automobile, the more fuel you must use to go each mile. On the other hand, if you drive your car very slowly, the fuel costs may be made small but the capital cost of owning the car will soon outweigh the fuel costs. It is literally true that "haste makes waste" in all of these processes. We may take these matters into account by making a graph, such as in figure 2, which shows the total cost per unit of water due to owning and maintaining the surface and the cost of energy as a function of the rate at which we force water through each unit of separating surface. Obviously there is an optimum. At the one end of the scale we have the badly overdesigned facility which uses very little energy but uses a great deal of capital, and at the other end of the scale we have the low capital investment which requires a great deal of energy to produce a given amount of water. The optimum lies in between. It is, of course, probably quite obvious to you that the best design depends on the original cost of the fuels, materials, and chemicals which are used up in the first place. If the fuels are expensive, it should be clear that a large capital investment can be justified. If the costs of the surface are high, then it is better to use more fuel. We may summarize this simple little analysis by writing a few equations. The total cost is the sum of capital and operating costs:

Total cost per unit of water = Capital cost per unit of water + Energy cost per unit of water

$$C_w = C_s \frac{A}{WL} + C_e \frac{E}{W}$$



In this equation, the symbols mean the following:

C_w is the cost per unit of water produced.

C_a is the cost of a square foot of membrane in place.

A is the area of the membrane.

L is the life of the membrane.

$\dot{W}$ is the rate of water production.

C_e is the cost of energy delivered to the surface.

E is the energy.

From the equation on figure 1 we replace the last term

$$C_w = C_a \frac{A}{\dot{W}L} + C_e R_m \frac{\dot{W}}{A}$$

and from the calculus we find the minimum cost

$$C_{w, \text{minimum}} = 2 \sqrt{\frac{C_a C_e R_m}{L}}$$

This equation summarizes in a greatly simplified way the results of the thermoeconomic study of the reverse osmosis system. It tells us that if we want to decrease the cost of the water produced in the reverse osmosis process, we must change one of four factors.

- (a) We can increase the life of the membranes.
- (b) We can decrease their resistance to waterflow.
- (c) We can make the membranes cheaper.
- (d) We can try to purchase the energy more cheaply.

But the equation also tells us this. Whatever changes we make in the membrane, the effect on the cost of the water is found through the ratio of these four factors. It does no good to increase the life of the membrane by a factor of two, if we have increased the cost by a factor of five. It does no good to decrease the resistance of the membranes, if, at the same time, we have decreased their life by the same amount. In short, unless one starts from a thermoeconomic analysis, such as I have presented here, one does not know how to distinguish between mere change and real economic progress.

I now wish to return to the three points which I said I would cover. The first point is that the emphasis of the Federal program has been badly misplaced. Consider, for example, part V, "Program for Advancing Desalting Technology." That part of the report discusses the work to be done in the improvement of the reverse osmosis system. If you will read that report, keeping in mind the simple analysis I have just made, you will see that there is no mention of the important factors which influence the economics of the process. For example, there are figures in the report concerning increased flux rates obtained with membranes. This corresponds to a decreased resistance in the membranes, but we are not told if the costs and the life of the membranes were altered in such a way as to provide more or less expensive water. Under the heading of "Membrane Research and Development," the report gives a description of various factors which will be studied. Nowhere in this report, however, is there any evidence that it is appreciated that the factors must be combined in the manner indicated in the above simple equation. We can go on spending money changing these four factors forever, without actually decreasing the cost of the resultant water.

Ever since the saline water program began, I have been observing with a mounting sense of frustration and concern that publicity agents for both the Government and private contractors continuously announce a significant "breakthrough" by claiming that one or another of these factors has been altered. They never state clearly what has happened to the other factors. The result has been to mislead the public and, I fear, the Members of Congress.

For example, in the conclusion to part I of the report I have just referred to, we read the following. "The multistage flash demonstration plant built by OSW at San Diego, was operated for 2 years and achieved a production rate 40 percent above design capacity." This is a totally misleading statement. As you saw in the last figure, there is an optimum operating point for every process. We can operate any plant in many different ways. To achieve increased production is not an accomplishment. What really counts is the cost of the water. Actually, my colleagues and I have published extensive analyses of this particular plant and we have reported that it was originally overcapitalized by about 30 percent in the first place. To refer to the increased waterflow as an "achievement" is to chase a false goal.

Because of the limitations of time this morning, I shall not continue to pile up example after example of how the Federal program has been carried out in almost total disregard of the lessons to be learned from this type of elementary analysis. I can assure you that, in view of the 13 years OSW has been in existence, I can produce examples of this sort for almost as long as you can afford the time to listen. I trust I have made the point that something significant has been lacking. I wish now to turn attention to why the Federal program has developed the way it has.

As I said in earlier remarks, the saline water program is in many ways radically different from other Federal R. & D. programs. Another distinction which must be made is that the leadership for this program has not been chosen the way we have chosen the leadership in other important R. & D. programs. In the Atomic Energy Commission, for example, we have always had topnotch men in the positions of leadership. Indeed, we have always had one or two Nobel Prize winners in the top level planning of that Commission. The result by and large, has been that we have seen first-class work from that body. Likewise, in the Space Agency we have recognized the need to place internationally

known and respected engineers and scientists in charge. On the other hand, in the case of the Office of Saline Water, the appointments to the directorship have in the past been made almost entirely on the basis of political considerations. The first director of OSW was a civil engineer who was replaced shortly after the program began.

The second director of OSW used to say quite frankly in public that he was not really qualified for his job. He had been trained as an M.D. and after an unsuccessful bid for reelection to political office had been given the post. His replacement was also obviously appointed on primarily political grounds. We now have a fourth director recently appointed by President Johnson. It is my judgment that the new director is fully qualified for the task and if given the right sort of support and the right climate, will bring to this Congress a sensible program which can advance the cause of sea water demineralization. But I hasten to point out that the program before us this morning is not his. It was put together by others who have not had the benefit of his technical direction.

If the water problem were not so laden with political and emotional considerations, it might not have been so important to have had adequate technical leadership. Unfortunately, as I study the record, I can only come to the conclusion that the Congress and the country must be protected from its natural inclinations to think that we can solve this problem simply by pouring in more money. The flow of fresh water is not going to be proportional to the flow of money. Indeed, I think perhaps the reverse could possibly take place. If we are to encourage private enterprise to play its role, we must not drive good engineering out by emphasizing bad engineering. We have a limited amount of technical ability in this country. If we swamp our talent with unrealistic and unlikely projects, we may in fact decrease our chances of success. This warning is not new before this committee. For example, during the hearings in August of 1961, Senator Allott said, "I am afraid of going ahead a bit too fast on the construction of various plants well beyond the strictly pilot stage before we have proven out any generally successful method." At several times during these hearings he asked some significant and pertinent questions but I am sorry to say that the general advice he received from most of the people who appeared before the committee was not sufficient to change the course of events.

In 1963 an article in Chemical and Engineering News, obviously submitted by the Public Relations Department of the Federal Office of Saline Water, begins in the following way:

"Now that the Department of Interior's Office of Saline Water has constructed or contracted for all of the plants scheduled under its initial demonstration plant program, increased emphasis will be placed on basic research in water technology."

In short, this is an admission that now that we have built the plants, we are going to do the research we should have done before we built these plants. The program that has been followed is completely reversed compared to the way an engineer responsible to stockholders would proceed to spend money. I consider it a failure of the engineering profession that we were not competent enough to redirect the program in 1961. The sad fact is that some very good questions put forth by Members of the Senate were answered rather badly by the witnesses and as a result the taxpayer's money has been wasted.

Part of the difficulty stems from the fact that this Nation is now in its 23d year of defense-type spending. Nearly a quarter of a century of "cost plus" engineering has had a very strong effect on both engineering education and engineering practices in this Nation. In times of war and in matters of national defense, we perhaps have no choice, and in matters involving totally new experiences, such as some forms of nuclear reactors or voyages into space, there is a need for extremely expensive experimentation. But in sea water demineralization we are not venturing into entirely new territory. We can duplicate at much less cost, and in smaller scale in our laboratories, all of the important things we need to learn. I am sure you know that parents can ruin their children by giving them unlimited allowances. In like manner you can ruin these engineering endeavors by supporting them too lavishly. When we know that a particular process for making fresh water from the sea is not economically attractive, what do we possibly gain by building a demonstration plant? If we lose a little bit on every gallon of water, we certainly can't hope to make it up by large volume.

In the spring of 1962 I visited Washington for a day to discuss these matters of economics with one of Secretary Udall's advisers. In his own field of science

he is quite competent, but like many of our scientists, he has a lot to learn about economics. I spent the entire day telling him about the way in which the economic and technical factors must be balanced if we are to make progress in the reduction of the cost of making fresh water from saline water. In March 1964, there appeared a report of an interagency task group, "An Assessment of Large Nuclear-Powered Sea Water Distillation Plants." The equations I had taught this fellow to use were repeated on page 27 of that report, and, unfortunately, badly misinterpreted as a careful study of that part of the report will show. The error is repeated in connection with the arguments used to justify the reverse osmosis scheme in the second sentence of part V of the report "Program for Advancing Desalting Technology," which reads, "This is so because the system is inherently simple and, unlike many other processes, no phase change is involved, reducing energy costs to an extremely low value." I remember particularly well trying to prevent the consultant from falling into the trap of thinking this was true. What disturbs me is that we have not had in OSW anyone of sufficient stature and competence in the field of thermodynamics and economics that errors of judgment of this kind could be prevented. Other comments which are equally revealing appear throughout the document and it is this fact which prompts me to urge you to make some changes in the pending legislation.

I trust that by now I have made the first two of my three points, namely, that the emphasis in our program has been misplaced and that there is a good reason for this misdirection. I now wish to turn our attention to what ought to be done about it. I propose to you that you modify the pending legislation in three important ways.

(a) First, I propose that you create an advisory commission on saline water conversion.

The Presidential Science Advisory Committee has strongly urged that every department of the Government engaged in research and development work ought to have an advisory committee which reviews the R. & D. programs of that department. The committee I have in mind ought to have on it men of unquestioned technical abilities. They ought to represent the disciplines of economics, chemistry, chemical engineering, mechanical engineering, civil construction, and operations research. The committee membership should include men of experience in water distribution, power production and sales, and in the development of chemical process equipment, such as, for example, is represented by the oil refineries. This commission should be nonpolitical in character, as are so many of the other advisory committees with which I am acquainted. The legislation creating the commission ought to require the concurrence of this commission in the programs submitted by the Office of Saline Water. Only in this way can we guarantee into the future the technical excellence that this program requires.

(b) Second, I propose that you make an appropriation which will carry the Federal Office of Saline Water for the next 2 years at a budget which is approximately 50-percent larger than the one they now have and that you set aside the present program.

This will give the new Director a chance to continue the basic and engineering studies but not to build new "demonstration" plants. It will also give him a chance to submit a new program. I remind you that the program before us is not his. It was put together under his predecessor and does not represent a coherent and logical development program. It would be unwise to saddle him with such an ill-conceived approach as has been thus far given to us.

(c) Third, I urge you to take steps to assure that the economic studies called for in the legislation of 1961 are actually carried out.

Even as late as 1962, the then Director of the program wrote me as follows: "Recognizing as you do the importance of economics to the problems of saline water conversion, the Office of Saline Water is establishing an economic group to undertake economic studies."

It is indeed disturbing to realize that OSW, as late as 1962, was just beginning to establish such a group. It should have been one of the first groups established in that Office.

The very final sentence of section V of the report "Program for Advancing the Desalting Technology" (almost as though it were an afterthought) states:

"In addition, an analysis will be made of each process to determine those components on which work should be concentrated."

I note however that such studies are not budgeted in the report.

It is a shocking admission that only now, after all these years, will the Federal program begin to use this sort of analysis in order to decide where to spend the taxpayer's money. I am confident that the new director of OSW is sensitive to these matters. But because the matter of properly directing our efforts is so critical, I urge you to consider legislation which will in fact insure that this kind of work is actually carried out. In this connection, may I call your attention to a report by the TVA, Technical Report No. 31, which describes an economic analysis of the Johnsonville steam generating plant. In this report, for example, it will be found that there are cost breakdowns on every item of equipment, every labor cost, including a breakdown by hours of labor, categorized as to type. I am referring here not only to the estimated costs but the final installed costs after the bids were acted upon. It is out of lessons such as this that engineers can decide how to improve their systems. I hope the director of OSW will gather similar data and I urge you to authorize a suitable budget for the purpose. In the absence of this sort of information, each construction job teaches a lesson only to the successful contractor, and if that contractor is not serious about his responsibilities, or does not wish to take the time to gather the necessary information, even he does not learn what can be learned from these jobs. To build "demonstration" plants and not record the most important data available from these plants is a shameful waste of the taxpayer's money. Indeed, if there is no intention to gather this sort of information, then, in my mind, there is really no need to build these plants in the first place.

In closing, I would also urge you to approve the request to establish and staff two research laboratories, one on each coast. These laboratories will have much work to do in the future.

The water problem will be with us for a long time to come and we must face the fact that we are in for a long tough job of constant cost reduction. I do not look for any great dramatic breakthroughs. Rather I look for a decrease in the cost of water as we apply ourselves steadily and patiently to the reduction of every item of cost in connection with the various processes. In short, we shall reach our goal only by hard, patient, sensible work. Let's organize to do it. Thank you.

Mr. ASPINALL. The Chair also has in his possession a letter from the Blaw-Knox Co., Pittsburgh, Pa., date of May 20, 1965, signed by Mr. Snyder, chairman of the board, in which he suggests their support of the continuance of the saline water program.

I would ask unanimous consent that this letter be placed in the record at this point.

(The letter follows:)

BLAW-KNOX Co.,
Pittsburgh, Pa., May 20, 1965.

HON. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
House of Representatives,
Washington, D.C.

MY DEAR MR. ASPINALL: With the holding currently of House and Senate hearings on the President's goal to economically produce potable water from saline water, I should like our company's views to be known as favoring continuation of the saline water program.

Blaw-Knox Co. has been actively engaged since 1959 in the development of a freezing process for desalination of salt water. We know that through our 3-year operation of a pilot plant in St. Petersburg, Fla., and the support of the Office of Saline Water, that genuine progress has been made toward development of essential information on the freezing process. Conservative estimates of water costs based on pilot plant operations indicate that in commercial plants of selected capacities it will be possible to produce potable water from sea water more cheaply by the freezing process on which we have worked than by others. Additional pilot plant development work will, however, be required before the final design and sizes of component equipment for commercial size plants can be determined.

It should be borne in mind that desalination of water by freezing processes is of comparatively recent origin. Yet, the progress that was made in the brief time the Blaw-Knox effort was maintained can be regarded as most encouraging.

We see the development of economic methods for the utilization of sea water

to supplement sources of natural water for general consumption as a highly important objective for this Nation. We believe the Congress should acknowledge the necessity of further and immediate development work to advance the remaining know-how required to permit the earliest possible move to commercial plant status in the desalination of water. In line with this view, we recommend strongly that the program for development work in saline water be continued and that the objective be supported in the current congressional hearings.

Further, we should like you to know of our willingness to appear before any congressional committee hearings on this subject, and will await your request to us for such participation.

Sincerely yours,

W. CORDES SNYDER, JR., *Chairman of the Board.*

Mr. ASPINALL. I also ask permission be given to have an additional statement from the company involved placed in the record at this point, provided they see fit, and it qualifies under our rules. Unless there is objection other letters or statements received by the committee may be included in the record if they qualify under the rules.

(Material submitted subsequent to the hearings follows:)

STATEMENT OF HON. HARRIS B. McDOWELL, JR., A MEMBER OF CONGRESS FROM
THE STATE OF DELAWARE

Mr. Chairman and members of the committee, I appreciate this opportunity to offer my views in strong support of H.R. 7092 introduced by the distinguished chairman, Hon. Wayne N. Aspinall and H.R. 8320 which I introduced on May 20, 1965.

These bills aim to meet the recommendations set forth by President Lyndon B. Johnson in his March 29, 1965, message to the Congress on the subject of saline water conversion.

There have been numerous scientific studies and reports on the need and techniques for providing adequate fresh water resources for people on all continents of this planet. Encouraging progress has been accomplished in the saline water conversion program underway in the U.S. Department of Interior as reported by Interior Secretary Stewart L. Udall in his testimony before this committee on H.R. 7092. Authorities at all levels of American Government are greatly concerned as to the urgent need for providing new sources of clean, potable, water for human and industrial consumption. The Department of the Interior reports that "no other resource commands a comparable percentage of departmental time, funds, and talent."¹

I read with great interest a recent article in a large metropolitan newspaper which reported that restaurants in New York City this week would not as a matter of course serve table water except by request of the patron. This unusual and unfortunate circumstance evolves from the misuse of existing water resources as well as a diminution in the rainfall on the eastern seaboard for the past 3 or 4 years. Below-normal rainfalls have made the vast population in this area and most parts of the United States conscious of the conservation of water resources as a part of daily human husbandry. In my own State of Delaware, which is to a large extent surrounded by large bodies of coastal waters, there is, paradoxically, a growing shortage of usable, fresh water resources.

As a study mission member of the House Foreign Affairs Committee, I have officially visited many foreign countries in Europe, Asia, and the Far East. I have observed that many of these countries are greatly handicapped in their efforts to provide food and other daily essentials for their citizens because of scarce or nonexistent water resources.

Mr. Chairman, I am confident that a scientific breakthrough can be achieved in the saline water conversion program for augmenting water resources provided by our annual rainfalls. Americans must be willing to apply the essential elements of finance, expertise, and technology to this human need which is universal to mankind and to all nations. I agree with President Johnson that the United States must assemble and employ these elements in making the oceans an eco-

¹ See U.S. Department of the Interior Conservation Yearbook, "Quest for Quality," published May 1965, p. 17.

nomical source of fresh water. The tax funds appropriated and spent to develop adequate water resources will bring incalculable and everlasting benefits for all peoples.

I respectfully urge the committee's favorable consideration of this legislation. Thank you, Mr. Chairman.

BLAW-KNOX Co.,
Pittsburgh, Pa., June 2, 1965.

HON. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
House of Representatives, Washington, D.C.

MY DEAR MR. ASPINALL: We appreciate the opportunity that has been provided whereby our company can file for the record in support of a continuation of the saline water program.

Attached is an account of our company's experience in research and development work on the desalination of water which may be helpful to a clearer understanding of the subject, its problems, and objectives.

Sincerely yours,

W. CORDES SNYDER, Jr.,
Chairman of the Board.

The Blaw-Knox Co. has been an active participant in the saline water conversion program since 1959. At that time, Blaw-Knox performed in Pittsburgh some of the first experimental work on the Cornell process of freezing with butane as the refrigerant. Simultaneously, experimental work was performed by Prof. H. F. Wiegandt at Cornell University. Successful experiments were followed by an engineering study by Blaw-Knox made for the Office of Saline Water, which indicated that potable water could be made by the process more cheaply than by other processes proposed at that time. Blaw-Knox then designed and built and operated for OSW a pilot plant at St. Petersburg, Fla. The pilot plant was operated for about 3 years, ending in May 1964.

After less than 2 years of intensive study of the new process, the pilot plant performed well. Compared with an original design production of 35,000 gallons of potable water per day, the pilot plant made water at rates in excess of 50,000 gallons per day. Even then, the major items of equipment had still greater potential capacity which could not be measured because the supporting equipment had not been designed for such overcapacity.

The freezer and washer-melter, the big items being studied, were then rebuilt to improve their performance and at the same time to reduce their size so as to bring their capacity into line with the rest of the pilot plant equipment. They were also made prototypes of equipment that would be used in a commercial plant, so that pilot plant results could be extrapolated with confidence. The pilot plant was then operated again. The revised equipment was just beginning to perform well when operation was suspended because OSW lacked funds to continue.

Operation just before shutdown was extremely encouraging. The plant was operated for short times at rates which were relatively three times that of the original design in terms of the performance of the major items of equipment that largely determine plant investment. Even greater production could be projected, since the plant was not yet operating at capacity. Additional experimental work would have demonstrated this increased capacity, and also that the operation could be sustained indefinitely as is required in a commercial plant.

Blaw-Knox has proposed that the pilot plant work at St. Petersburg be continued. The pilot plant is in standby condition, ready to be started again after minor repairs. Our proposal has been favorably received by OSW, who are just as anxious as we are to continue to work to the point where large plants can be designed and built. They still lack the necessary funds, but are hopeful that money will be available soon.

The Cornell freezing process using a secondary refrigerant is truly new. This is no background of commercial operation, as in evaporation, to use as a basis for plant design. Considerable development will be required before the process is commercial, but the effort is justified. Even on the basis of the small amount of pilot plant work performed so far, the process already appears competitive with evaporation processes in plants producing between 1 and 10 million gallons per day of potable water from sea water. Potable water made from brackish water by the process will be even cheaper. The process may well find its first commercial application in brackish water conversion.

In the Cornell process sea water, or brackish water, is partially frozen to a slush containing pure ice crystals suspended in brine. Freezing is accomplished by vaporization of butane (a cheap hydrocarbon widely available as a byproduct of the petroleum industry) in direct contact with the brine. Ice is washed free of brine, and melted by application of compressed butane vapor to the ice in a washer-melter of unique design that was developed in the pilot plant. The melted ice is the product water, part of which is recycled to the washer to wash the ice free of brine. An auxiliary refrigeration system holds the whole system at the subfreezing temperatures that are used in the process.

The advantages of the process, and the reasons why it deserves further development are the following.

1. The energy requirement, about 30 kilowatt-hours per thousand gallons of product, is unusually low. When coupled with the low capital cost that is promised by progress in equipment design, the combination means cheap potable water.

2. There are few heat transfer surfaces that can be clogged with scale deposited from the water. This means sustained plant operation without periodic shutdown for cleaning the equipment.

3. Low temperature operation in the absence of air minimizes the problem of corrosion. Carbon steel equipment can be used instead of expensive alloys. The 20- or 30-year plant working life which is commonly assumed in arriving at the cost of water ought to be realized in practice.

Because of these advantages, the Cornell process will find its place among those that will make cheap potable water in the future. Unlike evaporation, it requires no steam. Only mechanical energy is used, which may originate with electricity, gas, oil, or other fuel.

The Cornell process has been demonstrated as a potentially successful saline water conversion process. It will take additional experimental work in an existing pilot plant to improve the equipment so far devised and to show sustained operation. The process deserves continued support by the Congress and by the Office of Saline Water.

We urge that continued support of the Blaw-Knox pilot plant be made part of the program for saline water conversion.

CHAMBER OF COMMERCE OF THE UNITED STATES,
Washington, D.C., May 25, 1965.

Hon. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
U.S. House of Representatives, Washington, D.C.

DEAR MR. ASPINALL: In connection with your consideration of H.R. 7092, the Chamber of Commerce of the United States supports Federal saline water conversion research, provided that it is limited to fundamental scientific research, technological exploration and conceptual design.

We have two major areas of concern about the saline water research program: (1) The manner and extent to which the program is implemented and (2) The amount of funds to be authorized.

It is our position that the program should—

- (1) Be conducted by private enterprise insofar as possible. Government should only supplement private effort or perform such research as the private sector is unable or unwilling to perform.

- (2) Not include construction and operation of large-scale pilot plants capable of commercial production of potable water. This activity should be conducted by private industry or by the level of Government covering the area to be served by the facility, i.e., a town or city, a county or State, or perhaps a grouping of local and/or State governments in a regional compact.

- (3) Be compared on an economic basis with all other water research programs. This is essential to provide the most economical supply of water.

- (4) Ascertain the demand for desalinization in different areas of the Nation. A variety of water supply systems is indicated due to varying needs and supply sources.

We do not have adequate information upon which to base an informed recommendation as to the appropriation authorization. In transmitting to the appropriate congressional committees our recommendations with respect to the fiscal year 1966 budget request of the Interior Department's Office of Saline Water, we emphasized that:

"Any opposition to the enlargement of the saline water program stems from a concern about the feasibility of enlargement. It should be based on need and careful consideration must be given to the relation of cost to worth."

We would appreciate your giving careful consideration to these views and having them made part of the official record of your hearings on this legislation.

Sincerely,

Theron J. Rice, *Legislative General Manager.*

NATIONAL GRANGE,
Washington, D.C., May 25, 1965.

Hon. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: A prerequisite of any dynamic and growing civilization has historically been an abundance of fresh and pure water. The previous abundance of the supply of water meeting these specifications is seriously threatened at the present time by a fantastic increase in the amount of water demanded by industry, domestic household consumption, irrigation and general farm use, indicates that the available supplies of water are not going to be adequate for future needs of a growing America.

This is of major concern to the National Grange because of our fear that the demands for water by our urban and suburban friends will lead to a depletion of the available water supplies for agricultural purposes. We are also concerned because, without some very substantial increases in the source of water, both agricultural and industrial areas will suffer from the shortage.

Suggestions of eliminating the pollution of our streams, which the Grange vigorously supports, and of diverting water from one area to supply the needs of another, which the Grange does not entirely support, will not in our judgment furnish the amount of water that is needed by our population concentrations on either seaboard. Therefore, the only alternative, is the development of an efficient method of desalinization of ocean and sea water. With that in mind, the delegates to the 98th Session of the National Grange in Atlantic City, N.J., last November, passed the following resolution:

"We further recommend accelerated study with regard to desalinization." (P. 155, proceedings of the National Grange, 1965.)

The National Grange, therefore, urges the Committee on Interior and Insular Affairs' Subcommittee on Irrigation and Reclamation, to give their approval to H.R. 7092, in order to provide for accelerated research on a saline water conversion program.

Respectfully yours,

HARRY L. GRAHAM, *Legislative Representative.*

COLT INDUSTRIES, INC.,
Washington, D.C., June 1, 1965.

Hon. WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
U.S. House of Representatives, Washington, D.C.

MY DEAR MR. CHAIRMAN: Regarding H.R. 7092, I thank you deeply on behalf of Colt Industries for your request to report on the company's contract with the Office of Saline Water, on the company's own research activities, and on views with respect to the Federal program for desalting. We welcome the opportunity to submit the following statement.

Contract with Office of Saline Water

Colt Industries, Inc., 1290 Avenue of the Americas, New York, N.Y., has one contract with the Office of Saline Water. It was executed by the Department of the Interior on February 10, 1965. The Office of Saline Water contract number is 14-01-0001-532. This is the only contract with the Office of Saline Water which the company or any of its divisions has received.

The subject of the contract is the "Vacuum-Freezing Vapor-Compression Process" for the desalting of salt water. The process is based on a unique approach to desalting at low temperatures. A feature of it lies in the compression of large quantities of vapor within a small space. In the making of ice crystals it relies on the effect of vacuum. It does not require chemicals for secondary refrigeration.

The essential effectiveness of the process has been proved already by the company's own research and engineering program, which indicates possibilities of gains in the economics of sea water and brackish water conversion. In a long series of tests and operation at the company's Fairbanks Morse Power Systems Division plant in Beloit, Wis., the fresh water output of a module designed to produce 60,000 gallons a day has increased to more than 100,000 gallons a day without dimensional change of the module.

These tests have been made on closed loop with synthetic sea water. In order to measure precisely the economic implications of the process and to determine the outer limits of the amount of fresh water that can be produced in the module and to calculate the production that would be obtained from larger modules, it is necessary to continue the research at a sea water site in the United States where continued improvement can be sought under field conditions and the standards of the Office of Saline Water.

The purpose of the contract with the Office of Saline Water is to achieve the ends set forth in the preceding paragraph. The work under the contract is to be carried out at the Wrightsville Beach, N.C., facility of the Office of Saline Water. The contract is divided into two phases. Phase 1, in the amount of \$180,000, is now in effect; it provides for preparation of the Wrightsville Beach site, the removal of the module from Beloit to Wrightsville Beach, the erection of the module, and test. Phase 2, in the amount of \$294,000, provides for the developmental operation and evaluation of the plant at Wrightsville Beach. It also provides for Colt Industries to make preliminary cost estimates of desalting plants, using the process, capable of producing 1 to 5 million gallons of fresh water a day. The contract date for completion of phase 1 is August 28, 1965. The Office of Saline Water would not put the contract into effect for phase 2 until completion of phase 1.

Important points about which the experience on open-loop conversion at Wrightsville Beach should provide information critical for conversion economics are—

- (1) What is the response of the plant materials to deaerated cooled sea water under the vacuum conditions of the process? Is the reduction of the corrosion rate in cooled set water confirmed in the field?

- (2) By operating at low temperatures, the process seems to eliminate troublesome scaling, but the apparent absence of scaling needs to be checked in the field for complete answers.

- (3) What is the manpower requirement for operating a plant based on the process under field conditions?

- (4) What is the field power requirement?

- (5) What are the ambient losses in the field?

- (6) What is the effect of ocean water on the size and character of ice crystals in this process?

- (7) What are the ultimate capabilities of water production in this field situation at the ocean's edge? A factor in this capability is the amount of vapor that can be handled by the compressor. The outer limits of the compressor cannot be found at the factory.

Colt Industries has made no other installation or research contracts. Nevertheless, it has provided a conversion plant to Israel, under terms of the company's joint venture agreement with the State of Israel for control of the vacuum-freezing vapor-compression process. The Israel plant, installed at the town of Eilat in the desert by the Gulf of Aqaba, makes fresh water which is pumped into the town's water mains and which also is obtained at the plant itself by consumers using their own containers ranging from jugs to the tank trucks of resort hotels.

The Eilat plant, designed for production of 250,000 gallons a day of fresh water, consists of four modules, made in Beloit. The improved module which is being shipped to Wrightsville Beach has a capacity of fresh water production which was not available at the time the modules were shipped to Israel in May 1963. Eilat gives a demonstration of the ability of the process to produce potable water, but it does not serve the research purpose which is sought under the contract for Wrightsville Beach.

Company's own research activities

The transformation of the concept of the vacuum-freezing vapor-compression process into workable equipment began in 1960, after agreement reached in 1959 between the company and the State of Israel. The company, through the division at Beloit, undertook the industrial design of equipment and desalting plants

embodying the process, and Israel undertook basic research, which it continues at a center near Tel Aviv.

We would like to bring the committee's attention to three aspects of development at Beloit which are essential to the achievement realized to date in making the process capable of producing water. The line of development stresses cost savings:

1. Design of a radial centrifugal compressor capable of handling vapor in large volumes in confined spaces.

2. A specialized heat exchanger designed for the realization of low approach temperatures in order to conserve energy in the system and provide the necessary heat exchange at the lowest possible cost.

3. Modifications of the equipment that make the difference between the original design capacity of 60,000 gallons a day and the outputs of 100,000-and-over gallons a day realized with the present module: (a) Increased evaporation rates in the freezer due to agitation; (b) improved vapor condensation and melting system; and (c) improved compressor that utilizes a flow path more streamlined than the earlier compressor.

Tests of the conversion of salt water of low near-brackish salinity have been included in the development work at Beloit, with indications of markedly increased capacities without an increase in equipment size. Further testing is necessary to evaluate the potential economies for this use for the vacuum-freezing vapor-compression process.

Altogether the closed-loop test operation at Beloit produced 4,788,130 gallons of fresh water during the intermittent operational periods in 1964 from water of various salinities, high and low, fed into the module.

Colt Industries has spent in excess of \$3,500,000 on research and engineering in bringing the process to its present state of development. Israel has spent a similar amount. The research program of Colt Industries will go on concurrently with the work under the development contract at Wrightsville Beach. The company's own research will emphasize investigation of possibilities of larger modules. A staff is being maintained for the desalting program at the Fairbanks Morse Power Systems Division in Beloit.

Views with respect to the Federal program

We believe that system and hardware design, hardware manufacturing, and commercial plant construction are in general, clearly within the scope of industry's activity. Industry, to its own advantage, must make a continuing effort to improve design and manufacturing methods in order to reduce costs and thereby remain competitive in the market.

The joint efforts of industry and the Federal Government are necessary to determine the application and design parameters of each new process concept after industry itself has proved the concept's workability. This step in research and development and the economic studies which can be made possible by the research and development must involve the Federal Government because of the complexity of the entire water resources problem, particularly in view of the varying types and amounts of source waters available for processing from locale to locale, and in view of the effect of desalting plant operation in one locale on the water resources of the region. Industry alone is not equipped to penetrate this complexity, which involves questions both of the need of introducing converted sea water into a particular locale or region and of the approaches to be made in demineralizing brackish water.

The economic studies must be spearheaded by the Government if the interests of the taxpayers are to be protected. One can expect that a large number of the desalting plants in future use will be erected by cities, towns, or other political subdivisions; such subdivisions should have the opportunity, if they wish to seize it, of turning to an informed source for guidance in the selection of the conversion process and equipment best suited to need. With the limited experience of the world up to the present time in types of locales and kinds of equipment for desalting, the available economic data to the best converted water cost for most locales are inadequate. Discussion of economics has been focused mainly on the desirability of finding a way to get the cost of converted water down to some ideal universal price; the associated need is to assess the best economic approach for particular regions and sites, as the best achievable cost will probably vary from site to site. The ability to offer this sort of guidance depends on knowledge of resources and also on knowledge of the capabilities of the various conversion processes. Full development of the two kinds of knowledge requires effort by industry, political subdivision, and the Federal Government.

From this we conclude that the Federal Government has an important role to play in the development of equipment and guidance in the use of the developed equipment. It makes a contribution which at this time is unavailable from any other source.

Respectfully yours,

BLAIR BOLLES,
Vice President, Government Relations.

(Mr. J. F. Sinnott, president of the San Diego Gas & Electric Co., submitted the following statement and requested that it be included in the record.)

STATEMENT OF SAN DIEGO GAS & ELECTRIC CO.'S EXPERIENCES WITH SEA WATER
CONVERSION

The company's interest and active participation in the field of sea water conversion and evaporator operation dates back many years. Due to the geographic location of the company's service territory, the rapid population growth (which began about 1940) and the limited natural fresh water supply, it became obvious to management that research and development in the art of sea water conversion was most essential.

With concern for the economic well-being of the area we serve, and in the overall public interest, the company's engineers have, for many years, been actively engaged in studies concerning projects designed to supply both natural fresh water and converted sea water at the most economical level.

With the passing of time, our interest in the field of sea water conversion has greatly accelerated. In addition to our work in connection with the multistage flash evaporator, we have been closely associated with a reverse osmosis demonstration plant. We are also working with a third process not yet ready for announcement.

During the period when plans were being formulated for the first Point Loma plant, our engineers worked with those who were responsible for the location and design selection. We followed with interest the development and operation of the Point Loma unit.

A very brief summary of the company's more recent activities in the field of sea water conversion is as follows:

1. South Bay generating unit No. 2 at Chula Vista, Calif., provided our first flash evaporator to supply water for boiler makeup. This was placed in operation in 1962. This is the second such evaporator in the United States for the supply of boiler makeup.

2. To gain further experience and to bring about further improvements in design, the second such flash evaporator was installed with generating unit No. 3 in 1964.

3. Our work in the field of multistage evaporators resulted in a firm proposal which the company made in August of 1963. At that time we announced to the local water agencies our readiness to install a 25-million-gallon-per-day multistage flash evaporator which would be supplied with "bleed" steam from our South Bay generating unit No. 2.

Some additional details of this offer may be of interest. While South Bay unit No. 2 was not designed specifically as a generating unit which would also serve a 25-million-gallon-per-day flash evaporator, our engineers noted that the steam quality and quantity at the crossover between the intermediate- and low-pressure turbines approached very nearly the ideal situation.

After some detailed studies by our engineers, Westinghouse Corp. was invited to submit a proposal for a 25-million-gallon-per-day sea water flash evaporator to serve with South Bay Unit No. 2. Following a review of the work performed by company engineers, the Westinghouse Corp. submitted a firm "turnkey" proposal to provide the evaporator plant together with all necessary auxiliary equipment including a product delivery pump designed to operate at a discharge head of 100 feet.

It should be noted that the generating unit involved is rated at 150,000 kw, the average fuel cost at that time was 35.9 cents per million Btu's. The conversion plant was charged with its full share of power (both electric and steam), operation, maintenance and fixed charges (based on ownership by one or more of the local water agencies). The final cost of the converted water was set at 41.1 cents per 1,000 gallons, a firm price.

For a more detailed review of the proposal, we have attached an analysis which was formulated after presentation and evaluation by those concerned.

4. After a long period of study and laboratory development, conducted by Dr. Glenn G. Havens of Havens Industries, our company joined Dr. Havens to make possible a reverse osmosis pilot plant. In April of 1964, after a successful period of operation, we joined Dr. Havens in a public announcement at which time the demonstration plant was shown to leaders in Government, industry and business.

Credit for the conversion element goes to Dr. Havens who has now been joined by the Richfield Corp. We are continuing our work with Dr. Havens and our serious interest in what appears to be the most promising development of the time in sea water conversion.

5. On December 9, 1964, in a letter to Secretary Udall, company President J. F. Sinnott offered the U.S. Department of Interior a unique opportunity. This offer was made in the public interest to assist with the proposed west coast sea water conversion test facility. Due to the design and location of our South Bay powerplant, we believe the proposed facility can be installed and operated at an economical level not possible at any other site. In addition, there is a ready market for any product water plus multiple uses for the water in industry, agriculture, and for domestic purposes.

Other uses are possible in the immediate vicinity. There are some valuable domestic water wells nearby which have been rendered useless by reason of salt water intrusion. These wells may be rehabilitated through a process of "charging" with converted sea water. Also, a nearby saltworks would do doubt benefit if the discharged brine were made available for the evaporation ponds.

6. San Diego Gas & Electric Co. joined with the city of Los Angeles Department of Water and Power and Southern California Edison Co. in preparing and presenting a proposal to the metropolitan water district. This proposal, presented on April 8, 1965, opens the way to build and operate a nuclear powerplant-sea water conversion complex. The output of the sea water conversion plant would be 150 million gallons per day.

7. While details cannot be announced at this time, the company is currently planning with a prominent firm the building and operation of a second reverse osmosis prototype plant.

8. As a member of the Edison Electric Institute, the company is actively participating in a research project to evaluate sea water conversion and water supply.

Assuming for the moment that the final results, brought forth by research and development, indicate clearly that multistage flash distillation will be the most economical means to convert sea water, it does not necessarily follow that a dual-purpose plant will be employed in every case. To determine the proper heat source, it will be necessary to consider in detail the requirements for water and electric energy and coordinate the design of both elements of plant. Peaks and valleys of demand, the storage of water, interruptibility of waterplant, and many other factors loom large as we approach the time when a dual-purpose plant must be considered and built.

While it is too early to predict with any real assurance, our work with the reverse osmosis process indicates that this method may have greater potential than formerly believed possible. The simplicity of design, the low-power consumption, and the successful experience with the membrane have been very encouraging. It is possible that reverse osmosis may indeed replace flash evaporation as the most practical and economical process.

The foregoing is just a small part of that which makes the proposed test facility "a must." Not until this facility has had time to "prove" many concepts and designs will it be safe or prudent to proceed with a plant of any magnitude.

EVALUATION OF DUAL-PURPOSE SEA WATER CONVERSION PLANTS

In August of 1963 the San Diego Gas & Electric Co. proposed to the water agencies in its service territory that the company could modify its South Bay generating unit 2 to supply sufficient steam to operate a 25-million-gallon-per-day sea water conversion plant. The company offered to cooperate with any of the agencies which might wish to construct and operate the waterplant.

Estimated water costs

Estimated costs for producing water with this dual-purpose plant arrangement were as follows:

	<i>Cents per 1,000 gallons</i>
Fixed charges (waterplant only \$13,850,000 at 6 percent fixed charge rate)_____	10.1
Operation and maintenance_____	1.8
Chemicals_____	3.9
Electric energy and waterplant pumping_____	6.8
Equivalent cost of steam to waterplant_____	18.5
Total cost_____	41.1

The company was confident that this cost estimate was realistic in that the three principal items were known with a good degree of certainty. The company had in hand a proposal from Westinghouse Electric Corp. for turnkey construction of the 25 million gallons per day multistage flash evaporator unit. Cost of electric energy and steam to the waterplant was based on studies of an existing electric utility system and a specific steam-electric generating unit. The economic evaluation considered the effect of steam extraction for the water plant upon electric system fuel costs, taking into account the adverse effect upon equal incremental cost dispatching of all generating units on the system.

Contemplated mode of operation

The generating unit selected has a net electrical capability of 150,000 kilowatts with steam conditions of 2,000 pounds per square inch, 1,000° F., 1,000° F. The flash evaporator unit was to operate with an outlet brine heater temperature of 250° F.

Steam to the water plant was to be supplied by extraction from the cross-over pipe between the intermediate-pressure and low-pressure turbines. Sufficient steam flow was to be maintained through the low-pressure turbine to prevent low-pressure turbine overheating. The extraction steam pressure would be 50 pounds per square inch absolute.

Cost estimates were made on the basis of 90 percent load factor operation of the water conversion plant. With the waterplant producing full output, the net output of the generating unit would be reduced to 86 megawatts. In addition to reduced output because of steam extraction, 10.2 megawatts of this reduction was due to auxiliary power required for waterplant pumping. The contemplated method of operation was: (1) operate boiler continuously at full load steam output; (2) turbine-generator operated with control valves wide open and a net electrical output of 86 megawatts.

With the foregoing mode of operation the unit is capable of providing 74 megawatts of valuable spinning reserve capacity, assuming the waterplant operation could be interrupted. The cost estimate was based on an interruptible mode of operation and, hence, no capacity charge for the power generating unit was assigned to water cost. It was anticipated that interruptions would occur no more than four or five times per year and, normally, would be of short duration. The costs were based on an average fuel cost of 35.9 cents per million B.t.u.

Cost determination of heat supplied to waterplant

The cost of steam supplied to the waterplant was based upon the cost of fuel required for generation on other generating units as replacement for energy because of the reduced electrical output of South Bay 2. Since all of the system's generating units are dispatched on an equal incremental cost basis, this required determination of the effect on system incremental generating cost of the loss of output from South Bay 2. In the early years of operation, while South Bay unit 2 would be one of the most efficient generating units on the company's system, the system incremental costs are increased by reason of unavailable generation from unit 2. In later years, the system incremental fuel cost is increased because South Bay unit 2 must be maintained at 86 megawatts output, when on an equal incremental cost dispatching basis it would otherwise be operated at lower output or taken out of service altogether.

No study was made of the effect of operating the boiler at less than full output to produce less than 86 megawatts, electric, and 25 million gallons per day

water. It is possible that a more extensive study might disclose that the optimum mode of operation would be with variable boiler output. This type of optimization would require extensive computer simulation studies to produce valid results.

Response from local water agencies

After study of the company's proposal, the water agencies advised the company that the estimated cost of 41 cents per 1,000 gallons was not currently attractive to them since their cost of water was 7 cents per 1,000 gallons. Nevertheless, as discussions were held between the company and the water agencies, a number of rather interesting operational aspects of the proposed dual-purpose plant became apparent:

1. There is great concern on the part of the water agencies as far as the introduction of pure, unbuffered water into their distribution mains. Various schemes for blending the proposed 25 million gallons per day output with Colorado River water were discussed. The daily and seasonal flow rate in the city of San Diego distribution system varies widely. So widely, in fact, that it appeared impractical to introduce the waterplant output directly into the distribution system (if the plant were to be operated at 90-percent load factor). This meant that additional pumping costs would be incurred to pump the product water to reservoirs and treatment plants for blending.

2. Since water supply projects have traditionally required long leadtimes for design and construction, the availability of an offer to provide a site and steam supply for a waterplant provides the local water agencies with a degree of insurance should any of the long-term water supply contracts fail to materialize, or should water demands increase at a rate greater than predicted.

3. Evaporation losses from storage reservoirs in the area are a very significant item amounting to several hundred thousand dollars per year. It appeared that the use of the waterplant for supplying seasonal peak load requirements to forestall investment in additional reservoirs, with their attendant evaporation losses, should be further investigated.

4. There would be some benefit to the water users from diluting the high mineral content Colorado River water with relatively pure water, if the dilution rate can be maintained within reasonably close limits. Wide variations in water quality, even though all variations are in the direction of greater purity, are considered undesirable.

5. The water agencies are interested in a water conversion plant since it could provide water during emergencies and outages which might occur in the aqueduct systems supplying the area.

SDG&E conclusions based on August 1963 proposal and subsequent evaluation

In making its economic assessment of the proposed dual-purpose plant, SDG&E followed the currently accepted practice of assuming high-load factor operation of the waterplant. The high-load factor was assumed in order to demonstrate the lowest possible cost of product water. The company is now convinced that economic evaluation of dual-purpose plants, based on arbitrarily assumed high-load factor operation, has diverted attention from other modes of operation which are potentially more beneficial.

The approach in analyzing dual-purpose plants to date has been that of a "hardware" study rather than a "systems" study. Production of water in a dual-purpose plant requires coordinated design and operation of not just a powerplant and a waterplant, but of an electric generating and distribution system and a water gathering and distribution system. To date we are not aware of studies which have utilized such an approach.

More attention should be given to the use of dual-purpose plants for low-load-factor operation to meet peakload requirements for both electric and water systems. There appear to be many possible applications utilizing this mode of operation, or perhaps a mix of baseload and peaking plants just as with electric systems.

It further appears that the operating characteristics of electric and water systems are surprisingly similar; this, despite the fact that a water system can store water in reservoirs while storage of electricity at present can be accomplished only by pump-storage hydro installations. Nevertheless, it would appear that the concept of dispatching energy from electric generating resources on an equal incremental cost basis would be equally applicable to the dispatching of water supply resources. For example, despite the fact that millions of dollars

may have been invested in the capital cost of a power generating unit, once this capital has been invested the unit will be dispatched to provide energy to the electric system only if its output is equal to or less in incremental cost than other power sources. We can see no reason why the same concept is not also valid when determining from which resource water will be taken to supply a water system. For instance, it does not seem reasonable that a water system would call for water production from a sea water conversion plant at a cost of 40 cents per 1,000 gallons (20 cents or even 8 cents per 1,000 gallons) when there is water available to it through an aqueduct system at 7 cents per 1,000 gallons. Nevertheless, this does not mean that the waterplant does not have value as a standby and peaking resource. It is possible that it would be entirely economical to own and operate a waterplant under such circumstances to meet peakload water demands of relatively short duration in order to forestall the construction of additional aqueducts or reservoirs.

In line with the idea that dual-purpose plants might serve to supply peak water system loads, more consideration should be given to the use of existing powerplants as a heat source for the waterplant. It seems likely that under such conditions little, if any, capital cost of the electric plant need be charged against the waterplant.

The company believes that future studies of dual-purpose water conversion plants can be pursued with a much more imaginative approach than in the past. In any event, the company stands ready to assist as best it can the agencies supplying water to its service area.

NATIONAL RECLAMATION ASSOCIATION,
Washington, D.C., May 25, 1965.

Congressman WAYNE N. ASPINALL,
Chairman, Committee on Interior and Insular Affairs,
House Office Building, Washington, D.C.

DEAR CONGRESSMAN ASPINALL: Enclosed is a statement relating to H.R. 7092, saline water conversion, which I have prepared on behalf of the National Reclamation Association and which I would appreciate having inserted in the record for these hearings.

Respectfully,

WILLIAM E. WELSH, *Executive Director.*

STATEMENT OF WILLIAM E. WELSH, EXECUTIVE DIRECTOR, NATIONAL RECLAMATION ASSOCIATION

My name is William E. Welsh, I am executive director of the National Reclamation Association.

The future growth and prosperity of our Nation, as well as the health and well-being of our citizens, will depend upon an adequate supply of good quality usable water available at all times.

The seriousness of our encroaching national water crisis is recognized by all who have studied the problem in all of its aspects. This is a problem of serious and far-reaching implications to all Americans. The rapidly increasing demands on our available water supplies will soon require every American, whether he resides in an urban or suburban, industrial or rural area, to make water his own personal concern.

Donald A. Williams, Administrator, Soil Conservation Service, and one of the Nation's foremost authorities on land and water, at the national water research symposium sponsored jointly by our association and the National Association of Soil Conservation Districts, delivered a very significant address from which the following is quoted:

"Water, lifeblood of agriculture, of industry, of commerce, of life itself, cuts across every segment of our society, our economy, our daily lives. * * * The water business is serious business. It calls for our very best thinking, our best planning, action with a capital A and perhaps above all, the ultimate in coordination.

"The water supply problem is not one problem, but many. The solution is not one, but many. The people who must act are not few, but many. The people affected are not many, but everybody."

Water shortage in the arid and semiarid West has been a serious problem since the days when the covered wagon first carried immigrants to that area. For many years we thought of water shortage as being a problem only of the West—but during the past decade, it has become increasingly apparent that a national water supply which is adequate for the whole range of its uses will be a requirement and goal for all of America.

By the year 2000, our population will double and within another 35 to 40 years, it will double again, but the problems involved in maintaining an adequate supply of water for everyone is compounded by the fact that our demand for water per capita is constantly increasing.

The late Senator Robert S. Kerr, Oklahoma, who served as chairman of the Senate Select Committee on National Water Resources, in an address delivered before the same national water research symposium in Washington, D.C., said:

“* * * Water is the economic bloodstream of our Nation's economy. As never before, today's civilization requires more and more water to move its heavy cargoes, to cool its industrial plants and for disposal of its wastes. * * * Our national water supply situation is dynamic. The magic key to open tomorrow's doors is to solve its problems today. Action to avoid water difficulties, rather than efforts to correct them after they have occurred, must be taken if economic decline is to be avoided in many areas. Now is the time for a greater effort to find solutions to the problems that are already on the horizon.”

One area of the Nation in which the water situation is already acute—in fact it has been acute for sometime—is the Pacific Southwest. Adding to the seriousness of the situation in that area is the fact that the population is increasing at a tremendous rate. Citizens of the United States are not only moving westward, but they are really migrating to the Pacific Southwest at an almost unbelievable rate. The leaders of that area who are now uniting in an effort to find the solution and the answer to the critical water problem confronting them, are already looking forward to the possibility of importation of water—perhaps from a distance as far as 1,000 miles away.

The Board of Directors of the National Reclamation Association, in a letter addressed to the Members of the Congress from each of the 17 Western States a year ago, said:

“The Western water crisis, plus the great Western migration of our population, means that we must act today if we are to meet the problems of tomorrow.”

The Senate select committee, of which Senator Kerr was chairman, in its widely heralded report, pointed out that:

“* * * the Nation's water resources are not uniformly distributed in all the geographic regions. There are already substantial areas of water shortage in many of the river basins in the western half of the United States. On the basis of the water supply demand studies prepared under the foregoing assumptions, full development of all of the available water resources in 5 of the 22 water resource regions into which the contiguous part of the United States was divided for the purposes of the studies will be required by 1980 or earlier, if the projected increases in population and economic activity are to be achieved. These five regions are:

- “1. South Pacific.¹
- “2. Colorado River.
- “3. Great Basin.
- “4. Upper Rio Grande-Pecos River.
- “5. Upper Missouri River.

“By the year 2000 the following regions will be added to the list of those in which full development of available water resources will be required if the projected demands are to be met:

- “6. Upper Arkansas-Red Rivers.
- “7. Western Great Lakes.²
- “8. Western gulf.”

It behooves us as a Nation, in view of the critical situation confronting us, to employ and resort to all practical and legitimate means to augment our national water supply. We must strive to reduce losses through evaporation and transpiration. We must study means of controlling or eliminating water-loving

¹ It might be said that this region has already run out of water. Present deficiencies are being met by importation of water from other regions and plans are being made for additional importation from the central Pacific region.

² This is a special case, assuming availability only of runoff from U.S. portion of watershed and not considering additional use of Great Lakes water for waste dilution.”

plants (phreatophytes) ; we must study the problem of evaporation losses on large reservoirs, the loss of water through seepage and deep percolation. We must find better and more economical means of transporting water to areas where it is needed.

Already great strides have been made in our efforts to find an economical means of desalination of salt or brackish water although a breakthrough does not appear to be on the immediate horizon. But the progress that has been made surely justifies continuation of the program.

The Committees on Interior and Insular Affairs of both the Senate and the House are to be congratulated upon their vision and foresight in inaugurating this program. The progress that has been made to date is, to a very large extent, due to the farsighted judgment and action of the committees in initiating the desalination program in 1952.

We especially wish to compliment Senator Anderson and Congressman Aspinall for their initiative in sponsoring the act (Public Law 87-295) passed by the 87th Congress, which greatly accelerated the saline water conversion program. We also wish to congratulate these same two gentlemen as well as those who joined with them in sponsoring legislation now before this Congress which would authorize a substantial increase in the appropriations for the saline water conversion program.

The late President John F. Kennedy, in his well remembered natural resource message of 1962, said :

"The leadtime is long in the development of water resources. * * * Time should not be lost. * * * In the work of conservation, time should be made our friend, not our adversary. Actions deferred are frequently opportunities lost, and, in terms of financial outlay, dollars invested today will yield great benefits in the years to come."

On behalf of the board of directors and the entire membership of the National Reclamation Association, I wish to express my appreciation for the support which has been given to this program by the members of this committee.

Thank you very much indeed.

Respectfully submitted.

WILLIAM E. WELSH, *Executive Director.*

Mr. ASPINALL. The committee stands adjourned.

(Whereupon, at 5 :05 p.m., the committee was adjourned.)



LEGISLATIVE HISTORY

Public Law 89-118
S. 24

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INDEX AND SUMMARY OF S. 24

Jan.	6, 1965	Sen. Anderson, et al, introduced S. 24 which was referred to Senate Interior and Insular Affairs Committee. Print as introduced.
Apr.	5, 1965	Rep. Aspinall introduced H. R. 7092 which was referred to House Interior and Insular Affairs Committee. Print as introduced.
June	8, 1965	Senate subcommittee voted to report S. 24.
June	10, 1965	Senate committee voted to report S. 24.
June	14, 1965	Senate committee reported S. 24 without amendment. S. Report No. 319. Print of bill and report.
June	16, 1965	Senate passed S. 24 without amendment.
June	17, 1965	S. 24 was referred to House Interior and Insular Affairs Committee. Print as referred.
June	24, 1965	House subcommittee voted to report H. R. 7092.
June	30, 1965	House committee voted to report H. R. 7092.
July	7, 1965	House committee reported H. R. 7092 with amendments. H. Report No. 594. Print of bill and report.
July	12, 1965	House passed S. 24 with amendment (in lieu of H. R. 7092). H. R. 7092 tabled due to passage of S. 24.
July	14, 1965	Senate conferees were appointed on S. 24.
July	19, 1965	House conferees were appointed.
July	28, 1965	Conferees agreed to file a report.
Aug.	3, 1965	House received conference report. H. Report No. 720. Print of report.
Aug.	5, 1965	Both Houses agreed to conference report.
Aug.	11, 1965	Approved: Public Law 89-118.

Hearings: S. committee on S. 24
H. committee on H. R. 7092

DIGEST OF PUBLIC LAW 89-118

EXTENSION OF SALINE WATER CONVERSION PROGRAM.

Extends the saline water research and development program for 5 years through fiscal year 1972; authorizes an additional \$15 million to be appropriated for research and development work, which amount, added to previous authorizations, makes authorizations of \$35 million available after fiscal year 1966; and requires congressional approval for appropriations of amounts in excess of \$90 million, with such amounts limited to a total of \$185 million.

S. 24

IN THE SENATE OF THE UNITED STATES

JANUARY 6, 1965

Mr. ANDERSON (for himself, Mr. BIBLE, Mr. LONG of Missouri, Mr. MOSS, Mr. TOWER, and Mr. YARBOROUGH) introduced the following bill; which was read twice and referred to the Committee on Interior and Insular Affairs

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That in order to expand, extend, and accelerate the saline
4 water conversion program conducted by the Secretary of the
5 Interior, the Act of September 22, 1961 (75 Stat. 628), is
6 hereby amended as follows:

7 (1) In section 2 (b) add the words “, module, compo-
8 nent,” after the word “laboratory.”

9 (2) In section 8 substitute the figure “\$275,000,000”
10 for the figure “\$75,000,000” and the figure “1972” for the
11 figure “1967”.

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

By Mr. ANDERSON, Mr. BIBLE, Mr. LONG of Missouri, Mr. Moss, Mr. Tower, and Mr. YARROUGH

JANUARY 6, 1965

Read twice and referred to the Committee on Interior and Insular Affairs

H. R. 7092

IN THE HOUSE OF REPRESENTATIVES

APRIL 5, 1965

Mr. ASPINALL introduced the following bill; which was referred to the Committee on Interior and Insular Affairs

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That in order to expand, extend, and accelerate the saline
4 water conversion program conducted by the Secretary of the
5 Interior, the Act of September 22, 1961 (75 Stat. 628), is
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11 figure “1967”.

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

By Mr. ASPINALL

APRIL 5, 1965

Referred to the Committee on Interior and Insular
Affairs

Digest of CONGRESSIONAL PROCEEDINGS

OFFICE OF
BUDGET AND FINANCE

(For information only;
should not be quoted
or cited)

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. 20250

Official Business

Postage and Fees Paid

U. S. Department of Agriculture

Issued June 9, 1965

For actions of June 8, 1965

89th-1st; No. 103

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HIGHLIGHTS: House passed bill to continue export control. House committee reported cigarette labeling and advertising bill. House subcommittee approved cropland adjustment provision of farm bill. Senate passed Treasury-Post Office-Executive Office appropriation bill. Senate debated foreign aid authorization bill. Rep. Celler commended USDA's implementation of directives on civil rights.

HOUSE

1. EXPORT CONTROL. Passed, 387-1, as reported H. R. 7105, to continue the Export Control Act for 4 years. pp. 12375-92
2. TOBACCO. The Interstate and Foreign Commerce Committee reported with amendments H. R. 3014, to regulate the labeling and advertising of cigarettes (H. Rept. 449). p. 12427
3. CROPLAND ADJUSTMENT. The "Daily Digest" states: "Committee on Agriculture; On June 7 the Subcommittee on Conservation and Credit met in executive session and ordered reported favorably to the full committee the cropland adjustment provision of the farm bill." p. D495
4. LEGISLATIVE APPROPRIATION BILL. Passed without amendment this bill, H. R. 8775,

which includes items for the Government Printing Office and the Library of Congress. Regarding a new GPO building, the committee report states that construction funds were omitted from the bill "without prejudice to future reconsideration" because of uncertainty regarding the site and objections raised by the printing industry. pp. 12366-75

5. HOUSING. Rep. Barrett spoke in favor of early debate on the President's housing bill, H. R. 7984. pp. 12392-3
6. BUDGETING. Rep. Widnall spoke in favor of H. R. 8725, to modernize congressional budget review, subject the Budget Director and his Deputy to Senate confirmation, establish a Joint Subcommittee on the Federal Budget and Fiscal Policy in the Joint Economic Committee, and strengthen the functions of the General Accounting Office. pp. 12400-5

SENATE

7. TREASURY, POST OFFICE, AND EXECUTIVE OFFICE APPROPRIATION BILL, 1966. Passed as reported this bill, H. R. 7060. Senate conferees were appointed. House conferees have not yet been appointed. pp. 12332-6
8. FOREIGN AID. Continued debate on S. 1837, the foreign aid authorization bill (12310-32, 12342-3, 12363-4). Rejected by a vote of 29 to 11 an amendment by Sen. Proxmire to bar the use of Federal funds for the payment of barter agents' commissions, including those relating to CCC (p. 12332).
9. PATENTS. The Judiciary Committee reported with amendments H. R. 4185, to fix the fees payable to the Patent Office (S. Rept. 301). p. 12337
10. WATER RESEARCH. A subcommittee of the Interior and Insular Affairs Committee voted to report to the full committee without amendment S. 24, to expand, extend and accelerate the saline water conversion program conducted by Interior. p. D493
11. FOOD PRODUCTION. Sen. Simpson commended a report by Agricultural Economist Lester Brown, "Increasing World Food Output," and inserted two newspaper articles discussing this report. pp. 12345-7
12. WILDLIFE. Sen. Hruska spoke in support of his bill to permit the use within Canada of certain funds for the conservation of migratory waterfowl and inserted several articles on the subject. pp. 12347-8

ITEMS IN APPENDIX

13. DAIRY; FARM PROGRAM. Rep. McClory inserted Wisc. Gov. Knowles' speech paying tribute to American agriculture. pp. A2935-6
14. FOOD PRICES. Rep. May inserted an article, "Why Housewives Are Paying More For Food." p. A2938
15. ECONOMY. Extension/^{of remarks} of Rep. Martin criticizing economic policies of the administration and urging "a return to sound fiscal policies." pp. A2949-50
16. CIVIL RIGHTS. Extension of remarks of Rep. Celler commending this Department's action to implement congressional and executive directives regarding civil rights. pp. A2950-1

Digest of CONGRESSIONAL PROCEEDINGS

OFFICE OF
BUDGET AND FINANCE

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OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. 20250

Official Business

Postage and Fees Paid

U. S. Department of Agriculture

Issued June 11, 1965

For actions of June 10, 1965

89th-1st; No. 105

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HIGHLIGHTS: Senate debated foreign aid authorization bill. Several Senators discussed discontinuance of Mexican farm labor program. House Rules Committee cleared revised disaster relief bill. Rep. Nelsen criticized CSC's "delay" in investigation of "armtwisting" in REA. Sen. Ribicoff introduced and discussed bill to establish summer lunch program.

SENATE

1. FOREIGN AID. Continued debate on S. 1837, the foreign aid authorization bill. Agreed to, 73-13, a Harris amendment barring aid under this bill or certain agricultural sales to UAR or Indonesia while they commit aggression. pp. 12644-56, 12679-82, 12691-2
2. ARTS AND HUMANITIES. Passed with amendments S. 1483, to establish a National Foundation on the Arts and Humanities, including a provision requiring the Federal Council to promote coordination between the programs of the Foundation and related programs of other Federal agencies. pp. 12635-43
3. FARM LABOR. Sens. Murphy, Holland, and Williams of N. J. discussed the effects of discontinuance of the Mexican farm labor program. pp. 12695-709
4. APPROPRIATIONS. The agricultural subcommittee of the Appropriations Committee

concluded its hearings on H. R. 8370, the agricultural appropriation bill. p. D509

Received from the Calif. legislature a resolution opposing the proposed discontinuance of utilization research on western rice. pp. 12721-2

Received from the Okla. legislature a resolution recommending continuation of the Agricultural Conservation Program at the current \$250,000,000 level. p. 12722

5. FARM PROGRAM. Sen. McGovern inserted statements regarding the "farm crisis in South Dakota" as a result of decreased farm income. pp. 12742-6
6. EXCISE TAXES. The Finance Committee voted to report (but did not actually report with amendments H. R. 8371, to reduce or repeal certain excise taxes. p. D509
7. POVERTY. Sen. Proxmire defended administration of the poverty program. pp. 12685-90
8. FOREIGN TRADE. Sen. Proxmire inserted and commended a speech by Federal Reserve Board Member Robertson, "The Balance-of-Payments Problem, Short-Term Relief and Long-Term Remedy." pp. 12692-5
9. PERSONNEL. Sen. Hartke spoke on the "dangers" of appointing military men to civilian positions. pp. 12709-20
10. RECLAMATION; ELECTRIFICATION. The Interior and Insular Affairs Committee reported with amendments S. 599, to authorize the Auburn-Folsom south unit, American River division, Central Valley project (S. Rept. 312); and without amendment S. 1761, to authorize a third powerplant at the Grand Coulee Dam (S. Rept. 314) p. 12724
This Committee also ordered reported (but did not actually report) S. 602, to broaden the scope of the Small Reclamation Projects Act (amended), and S. 32 authorizing the southern Nev. water project (amended). pp. D509-10
11. WATER RESEARCH. The Interior and Insular Affairs Committee voted to report (but did not actually report) S. 24, to increase authorizations for expansion and extension of the saline water conversion program. pp. D509-10

HOUSE

12. FLOOD CONTROL. Concurred in Senate amendments to H. R. 6755, authorizing additional appropriations for prosecution of projects in certain comprehensive river basin plans for flood control. This bill will now be sent to the President. pp. 12750-1
13. DEPARTMENT OF INTERIOR AND RELATED AGENCIES APPROPRIATIONS BILL, 1966. Conferees were appointed on this bill, H. R. 6767. Senate conferees have already been appointed. p. 12751
14. MILITARY CONSTRUCTION. Passed as reported H. R. 8439, to authorize certain construction at military installations. The bill includes authorizations for payments to the Commodity Credit Corporation for having financed certain family housing through the sale of surplus agricultural commodities. The bill also contains a committee amendment which Rep. Rivers maintained is constitutional, to provide a waiting period prior to executive base closings and provide a mechanism whereby Congress could reject the proposed executive actions. pp. 12752-3, 12758-97

Digest of CONGRESSIONAL PROCEEDINGS

OFFICE OF
BUDGET AND FINANCE

(For information only;
should not be quoted
or cited)

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.

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HIGHLIGHTS: Senate passed foreign aid authorization bill. Senate debated International Wheat Agreement. Senate committee reported bill to expand salt-water research. House received conference report on Interior appropriation bill. House Rules Committee cleared housing bill. House Rules Committee cleared revised disaster relief bill. House committee voted to report bill to provide diversion payments on acreage affected by disaster.

SENATE

1. FOREIGN AID. Passed, 68-20, with amendments H. R. 7750, the foreign aid authorization bill. Senate conferees were appointed. pp. 12989, 13008-40, 13043-67
2. WHEAT. Began debate on ratification of protocol extending the International Wheat Agreement for 1 year. pp. 13069-70
3. WATER RESEARCH. The Interior and Insular Affairs Committee reported without amendment S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Interior Department (S. Rept. 319). p. 12957
4. EXCISE TAXES. The Finance Committee reported with amendments H. R. 8371, to reduce or repeal certain excise taxes (S. Rept. 324). p. 12957
5. ELECTRIFICATION. Received from REA a report on approval of a loan to the Lower

Colorado River Authority, Tex. p. 12957

6. SOIL CONSERVATION; APPROPRIATIONS. Received a N. C. legislature resolution opposing proposed reductions in soil-conservation appropriations. pp. 12974-5
7. LEGISLATIVE PROGRAM. Sen. Mansfield stated that it is planned to complete action on the International Wheat Agreement today, followed by the excise tax bill, the debt limit bill, and the cigarette labeling bill. p. 13040

HOUSE

8. INTERIOR AND RELATED AGENCIES APPROPRIATION ACT, 1966. Conferees filed a report on this bill, H. R. 6767, (H. Rept. 513). (pp. 1291-14). At the end of this Digest is a table showing the action of the conferees on Forest Service items. The conferees also provided an allocation of \$17,300,000 to the Forest Service from the Land and Water Conservation Fund instead of \$12,000,000 as proposed by the House and \$19,785,150 as proposed by the Senate.
9. HOUSING; URBAN DEVELOPMENT. The Rules Committee reported a resolution for the consideration of H. R. 6927, to establish a Department of Housing and Urban Development. p. 12914
Rep. Patman commended and inserted an article, "Small Communities--Getting Many Federal Aids as Part of Urban Development." pp. 12928-30
10. DISASTER RELIEF. The Rules Committee reported a resolution for the consideration of S. 2089, the revised disaster relief bill. pp. 12914-5
11. FEED GRAINS. The Agriculture Committee voted to report (but did not actually report) H. R. 8620, to take into consideration floods and other natural disasters in reference to the feed grains, cotton, and wheat programs for 1965.
Rep. Michel spoke in opposition to H. R. 8629, to amend the provisions of the wheat program authorized in the Agricultural Act of 1964, which he stated "would injure Illinois industry and Illinois farmers by subsidizing wheat for industrial uses at the expense of corn." pp. 12948-9
12. WATER POLLUTION. Rep. Kunkel urged action on the proposed Water Quality Act of 1965. p. 12926
13. WILDERNESS. Rep. Olsen, Mont., inserted a newspaper article discussing the controversy over the classification of the Selway-Bitterroot area as a wilderness area. pp. 12961-2
14. WILDLIFE. Received from Interior a proposed bill to provide for the conservation, protection, and propagation of native species of fish and wildlife, including migratory birds, that are threatened with extinction, and to consolidate the authorities relating to the administration by the Secretary of the Interior of the national wildlife refuge system; to Merchant Marine and Fisheries Committee. p. 12954
15. TARIFFS. Received an Ariz. Legislature memorial "opposing the passage of H. R. 8147 relating to reducing the existing tariff schedules." p. 12955
16. EXTENSION WORK. Received an Hawaii Legislature memorial "requesting that the Morrill Act be amended so as to enable States to invest their grants in corporate equities." p. 12955

ACCELERATED PROGRAM TO ADVANCE DESALTING
TECHNOLOGY

JUNE 14, 1965.—Ordered to be printed

Mr. ANDERSON, from the Committee on Interior and Insular Affairs,
submitted the following

R E P O R T

[To accompany S. 24]

The Committee on Interior and Insular Affairs, to whom was referred the bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, having considered the same, report favorably thereon without amendment and recommend that the bill do pass.

Committee action in ordering S. 24 reported favorably without amendment was unanimous. The measure was specifically requested and wholeheartedly endorsed by the President of the United States in a special message to the Congress on March 29, 1965. Open public hearings were held on the measure at which spokesmen from the Department of the Interior, the Atomic Energy Commission, the Office of Science and Technology, and representatives of private industry and research groups expressed vigorous support.

PURPOSE OF THE BILL

The purpose of S. 24 is to provide for an expansion of the Federal program or research and development in the field of saline water conversion, through authorization of an additional \$200 million of appropriations for the period ending fiscal year 1972. Under the existing program, the technology of water desalting has been advanced to the point where it promises that fresh water can be produced from the sea in large combined distillation and electric power generating plants at a cost estimated at 30 to 35 cents per thousand gallons of water, and about 3 mills per kilowatt hour for electric power. Such costs for water, however, can only be achieved by the construction of a desalting plant about 100 times larger than any yet constructed. Such an increase in size over existing plants presents a number of

engineering challenges that must be overcome before an actual operating plant can be shown to be feasible for meeting actual needs.

Substantial investments in engineering and testing of large-scale components, modules, or sections of plants will be required to show that the distillation process will actually produce the results calculated. In addition, an increase in the scale of research and development work on other desalting and demineralizing processes is desirable at this time to develop techniques that will be useful in dealing with a number of water problems in the inland parts of the Nation.

S. 24 will permit roughly a fourfold expansion of the research program. It is intended to lead, within the next few years, to recommendations for the construction of one or more large-scale desalting plants that can fill a real need through the production of water for the growing population and industry of America.

HEARINGS

The Subcommittee on Irrigation and Reclamation held open public hearings on May 18 and 19, 1965, to review the current status of the desalting program and to hear testimony on the extension proposed in S. 24. Information on the present program and justification for the proposed increase was presented by Secretary of the Interior Udall and by the new Director of the saline water research program, Mr. Frank DiLuzio. Other governmental witnesses were Dr. Donald Hornig, Director of the Office of Science and Technology in the Executive Office of the President, and Commissioner James T. Ramey of the Atomic Energy Commission, who testified from the viewpoint of the relationship of the proposed increases to the atomic energy research program. More than a dozen representatives of industries interested in the development and utilization of desalting techniques testified in support of the increased authorization, with particular reference to the process in which they were interested. Many of the witnesses suggested that the time was now at hand for construction of a large-scale prototype plant making application of the principles developed by the program so far. A spokesman from the academic world criticized the existing program, and made three suggestions for its improvement. These were (1) the establishment of an advisory commission to guide the activities of the Office of Saline Water (2) that the program be continued for the next 2 years at a level about 50 percent larger than at present, and (3) that greater attention be given to assuring that the program is directed toward meeting the needs of the marketplace.

In concluding the hearings, the Director of the Office of Saline Water responded to the comments and suggestions made by the preceding witnesses. He pointed out the need for further research, engineering, and testing, as well as economic and market studies before the program moved into the construction stage. He stated that he has already taken steps toward the creation of advisory committees, that the full increase in the program proposed by S. 24 is needed because of the size of some of the desalting plant components that need to be fabricated and tested to achieve an acceptable level of technology prior to the construction of the first large plant, and that the Office of Saline Water had no intention of building a large-scale plant unless it could fill a demonstrated market need for pure water.

OPERATIONS UNDER THE SALINE WATER CONVERSION PROGRAM

The saline water conversion program began during the Truman administration under legislation approved July 3, 1952. The program was carried on through grants and contracts for research and development work performed by public and private institutions, and corporations, by private individuals, and by other agencies of the Federal Government. The initial authorization provided \$2 million for a 5-year period. In 1955, the authorization was increased to \$10 million and the life of the program was extended to 1963. A number of pilot plants to test various processes were constructed, and a research and development test station was established at Wrightsville Beach, N.C., to provide a facility for the testing and development of desalting processes in pilot plants operated under standardized conditions.

Demonstration plants.—Under Public Law 85-883, approved September 2, 1958, five demonstration plants were authorized for construction, one each on the Atlantic, Pacific, and Gulf coasts, and two in the interior regions where brackish underground waters are found in great abundance. Under this 7-year, \$10 million program, plants to demonstrate the following processes have been constructed:

Process	Size (gallons per day)	Location
Long-tube-vertical, multiple-effect distillation.....	1, 000, 000	Freeport, Tex.
Multistage flash distillation.....	1, 000, 000	San Diego, Calif.
Electrodialysis.....	250, 000	Webster, S. Dak.
Vapor compression distillation.....	1, 000, 000	Roswell, N. Mex.
Freezing.....	200, 000	Wrightsville Beach, N.C.

The Freeport, Tex., plant, using the long-tube-vertical, multiple-effect distillation process, was completed in May 1961. Almost 1 billion gallons of water have been produced for the plant's customers during the past 3½ years. In the course of its operation, many components have been replaced and other modifications have been made to improve the plant's operation, and the plant is now producing at its rated capacity of 1 million gallons per day.

The multistage flash distillation plant at San Diego, Calif., operated successfully for almost 2 years, producing more than 500 million gallons of fresh water delivered to the city of San Diego, prior to its transfer last February to Guantanamo to meet the Navy's emergency need. By increasing the plant's operating temperature from 190° F. to 250° F., the output of the plant was increased 40 percent to the 1,400,000 gallons per day, with only a slight increase in operating costs.

The 250,000-gallon-per-day electrodialysis plant at Webster, S. Dak., has processed all of the water for the city since March 1962. This plant has achieved all reasonable expectations and has been on-stream about 90 percent of the time.

The 1-million-gallon-per-day brackish water vapor compression distillation plant at Roswell, N. Mex., was completed in July 1963. It has not yet operated at its designed capacity or for any extended period of time because of numerous problems that have arisen. Performance of the plant has been improved, but further changes will be necessary before it can operate successfully.

The freezing process demonstration plant at Wrightsville Beach, N.C., is in reality a large-size pilot plant, since the bids received for the construction of the plant made it obvious that the freezing process had not yet been developed to the point where a freezing plant could be expected to operate continuously and provide economic information expected from a demonstration plant. Construction of the pilot plant, with a design capacity of 200,000 gallons per day, was completed in July 1964. Mechanical difficulties, along with some design problems have prevented successful operation and fresh water production.

EXPANSION OF RESEARCH PROGRAM

The Anderson-Aspinall Act of September 22, 1961, permitted a substantial increase in the research program conducted by the Office of Saline Water, through its authorization of appropriations of \$75 million for the period ending in fiscal year 1967. Emphasis of the expanded program was focused on basic research, rather than the construction of pilot plants, and a remarkable increase in fundamental scientific information relating to desalting has been achieved. This, coupled with the operating experience gained from the operation of the demonstration plants, has set the stage for a major leap forward in development of desalting techniques, which it is believed can be achieved through the construction of a large-scale distillation plant coupled with an electric power generation plant to help meet growing needs for fresh water in southern California.

Thus, at present, under its new Director, the Office of Saline Water is undergoing a major transition from research and small plant engineering to a full-scale engineering program for large plants. This includes work in cooperation with the Atomic Energy Commission on dual purpose plants in which nuclear energy will be used as the heat source both for distillation of sea water and for production of electric power. A report suggesting such a plant was made by scientists at the Los Alamos Laboratory of the Atomic Energy Commission as early as 1956, and the idea has been developed cooperatively by the Office of Saline Water and the Atomic Energy Commission. An interagency task group appointed by the Office of Science and Technology made a more detailed report in March 1964, on the basis of which the President directed the agencies to proceed with the development of an expedited program for advancing desalting technology. These developments have provided the basis for the program expansions proposed by S. 24.

On August 18, 1964, the Department of the Interior, with the participation of the Atomic Energy Commission, contracted with the Metropolitan Water District of Southern California to undertake an engineering and feasibility study of a combined desalting and generating plant within the ranges of 50 to 150 million gallons of water per day and a capacity of 150 to 750 megawatts of electricity. The study is scheduled for completion by October 1965, and if the preliminary studies show the project to be economically attractive, the report will form the basis for appropriate decisions regarding the direction to be followed in future saline conversion plants.

The program has important international implications, and the Office of Saline Water is cooperating with many foreign nations that are interested in desalting as a means of augmenting their water supplies. Later this year in Washington there will be an International

Conference on Desalination, where it is hoped much information will be presented and shared by all nations participating. In his support for this program, President Johnson has stressed its potential for relieving many of the water problems that now present difficult situations between and within various nations.

Appropriations for the saline water conversion program are summarized in the following table.

Fiscal year	Salaries and expenses of research program	Demonstration plant construction, operation and maintenance	Total program
1953.....	\$175, 000		\$175, 000
1954.....	400, 000		400, 000
1955.....	400, 000		400, 000
1956.....	600, 000		600, 000
1957.....	550, 000		550, 000
1958.....	725, 000		725, 000
1959.....	¹ 1, 182, 960		1, 182, 960
1960.....	1, 755, 000	\$1, 850, 000	3, 605, 000
1961.....	1, 755, 000	2, 040, 000	3, 795, 000
1962.....	5, 255, 000	4, 550, 000	9, 805, 000
1963.....	7, 600, 000	2, 000, 000	9, 600, 000
1964.....	10, 000, 000	1, 850, 000	11, 850, 000
1965.....	10, 000, 000	2, 250, 000	12, 250, 000
1966 ²	³ 20, 030, 000	2, 485, 000	22, 485, 000
Total.....	60, 397, 000	17, 025, 000	77, 422, 960

¹ Includes \$33,000 for preliminary work on demonstration plant program.

² Recommended in H.R. 6767.

³ A reduction from \$26,515,000 recommended in the President's budget.

NEED FOR THE BILL

The Nation is confronted with a wide range of water resources problems to which a solution must be found if our standard of living is to continue to advance while our economy grows. Not the least of these problems is that of assuring sufficient supplies of fresh water at reasonable cost, to meet the needs of population, industry, and agriculture over the years ahead.

The 1961 Report of the Senate Select Committee on National Water Resources stated:

* * * The importance of Government policy in meeting the water resources problems ahead cannot be denied. The recommendations which follow are based on the committee's belief that future demands can be met best by finding the proper combination of (a) construction programs; (b) scientific research; (c) development of known technical methods; and (d) strengthening of Government policies affecting water development and use. Such a combination of efforts cannot be achieved overnight, and will require the combined efforts of the legislative and executive branches of the Federal Government, as well as a continuation and strengthening of work in these fields of State and local governments and private enterprise.

All of these approaches listed by the committee are embodied in the saline water conversion program, the 1961 expansion of which was one of the first Federal research programs to be acted on following the recommendations of the select committee. If the successful partnership that has been worked out between the Office of Saline Water and

private industry in advancing desalting technology is to provide a means of augmenting the Nation's water supply at reasonable cost, then a major acceleration beyond what was authorized in the 1961 legislation is clearly required. Basic research and the five demonstration plants that have been constructed have advanced technological development to the point where a substantial increase in funds must be provided if we are to continue to progress at a pace which will produce the results that the Nation's projected water needs make mandatory in the next decade.

The \$200 million expansion of the program provided in S. 24 is aimed at accelerating the rate of technological progress toward the twin goals of reducing the costs of purifying sea water to a point where the large coastal metropolitan areas may look at the sea as an economical source of fresh water, and reducing the costs of treating brackish and other chemically charged water so that inland communities and industries will be able to make better use of the supplies that are available. One of the important uses for the techniques that are being developed for dealing with brackish and other chemically charged water is in pollution abatement, and the committee expects the Office of Saline Water to maintain a continuing liaison with scientists of the Department of Health, Education, and Welfare, to the end that developing techniques will be made available for pollution abatement.

While S. 24 does not authorize the construction of any more demonstration plants, the committee anticipates that it will stimulate the advance of desalting technology to the point where a recommendation for a large size plant can be considered in the near future.

EXECUTIVE COMMUNICATION

The President's message to Congress recommending enactment of legislation to increase the saline water conversion program is set forth in full below.

THE WHITE HOUSE,
Washington, March 29, 1965.

HON. HUBERT H. HUMPHREY,
President of the Senate,
Washington, D.C.

DEAR MR. PRESIDENT: Past generations of Americans have been blessed with an abundance of sparkling, clean water. But in recent years we have become careless in our stewardship of this vital resource—polluting, wasting, and carelessly exploiting it.

Water shortages—real as well as prospective—already plague some regions of our land. Other areas and communities will soon be threatened. Yet, we must have an abundance of fresh water if we are to continue to grow and prosper.

Action to conserve what nature has so generously provided has often been inadequate and too late. We are determined not to make this mistake again. I have already pledged full support for cleaning up our rivers—and keeping them clean. We will continue to foster conservation by planning for the wisest possible use of all existing water supplies and by curbing and eliminating wasteful and uneconomic uses of water.

But these steps are not enough. New sources of supply at competitive costs are also required if we are to stay abreast of the ever-

mounting demand for water. The seas around us offer an inexhaustible reservoir to help meet this need in coastal areas while vast quantities of brackish water are available to supplement the supplies of many inland areas. We must spare no effort in learning how to desalt these waters economically.

For the past 12 years the United States has been engaged in a program of research and development which has brought desalting technology to a point where it shows promise of economic application in the future. To stimulate the translation of this promise into reality, I requested the Department of the Interior last July to develop, in close collaboration with the Atomic Energy Commission, a proposed program which would significantly advance large-scale desalting technology.

The resulting report entitled "Program for Advancing Desalting Technology" was completed promptly and released to the public on October 26, 1964. It recommended—and I am transmitting with this letter draft legislation to accomplish—expansion, extension, and acceleration of the salt-water conversion research and development activities now being conducted by the Department of the Interior under authority of the Anderson-Aspinall Act of 1961.

This legislative proposal would increase by \$200 million the \$75 million appropriation authorization provided in the 1961 act and extend through 1972 the time during which the authorized funds would be available to support this important program. Enactment of this legislation is vital if the Department of the Interior is to mount and lead the substantial sustained effort necessary to achieve truly economical desalting of sea and brackish waters.

In the meantime, I have already transmitted to the Congress a request for a supplemental appropriation of \$3.9 million in 1965 to enable the Department, through a reorganized Office of Saline Water, to accelerate its research and development activities along the general lines outlined in the report mentioned above. Desalting activities will receive continuing emphasis in 1966. My budgetary recommendations to Congress for the coming fiscal year amount to \$29 million for the Office of Saline Water, more than double the amount appropriated for 1965.

By pressing ahead with a vigorous program of economic desalting to meet our ever-growing domestic needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage. To stimulate cooperation in the field with such great potential for the good of mankind, the United States will convoke a symposium of interested nations in October 1965 to exchange information on desalting technology.

In recommending this measure to the Congress, I wish to acknowledge the foresight of such able legislators as Clinton Anderson, Wayne Aspinall, and the late Clair Engle. Our present efforts in desalting rest in substantial measure upon the sound foundation they laid and on which we intend to build. I earnestly hope that their leadership and the progress which it has inspired can be carried forward without

interruption by the prompt enactment of the bill I am transmitting today.

Sincerely,

LYNDON B. JOHNSON.

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words “, module, component,” after the word “laboratory”.

(2) In section 8 substitute the figure “\$275,000,000” for the figure “\$75,000,000” and the figure “1972” for the figure “1967”.

CHANGES IN EXISTING LAW

In accordance with subsection (4) of rule XXIX of the Standing Rules of the Senate, changes in existing law made by the bill, S. 24, as reported, are shown as follows (existing law proposed to be omitted is enclosed in black brackets, new matter is printed in italic, existing law in which no change is proposed is shown in roman):

ACT OF SEPTEMBER 22, 1961 (75 STAT. 628)

To expand and extend the saline water conversion program being conducted by the Secretary of the Interior

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951-1958), is further amended to read as follows:

“SECTION 1. In view of the increasing shortage of usable surface and ground water in many parts of the Nation and the importance of finding new sources of supply to meet its present and future needs, it is the policy of the Congress to provide for the development of practicable low-cost means for the large-scale production of water of a quality suitable for municipal, industrial, agricultural, and other beneficial consumptive uses from saline water, and for studies and research related thereto. As used in this Act, the term ‘saline water’ includes sea water, brackish water, and other mineralized or chemically charged water, and the term ‘United States’ extends to and includes the District of Columbia, the Commonwealth of Puerto Rico, and the territories and possessions of the United States.

“SEC. 2. In order to accomplish the purposes of this Act, the Secretary of the Interior shall—

“(a) conduct, encourage, and promote fundamental scientific research and basic studies to develop the best and most economical processes and methods for converting saline water into water suitable for beneficial consumptive purposes;

“(b) conduct engineering research and technical development work to determine, by laboratory, *module, component*, and pilot plant testing, the results of the research and studies aforesaid in

order to develop processes and plant designs to the point where they can be demonstrated on a large and practical scale;

“(c) recommend to the Congress from time to time authorization for construction and operation, or for participation in the construction and operation, of a demonstration plant for any process which he determines, on the basis of subsections (a) and (b) above, has great promise of accomplishing the purposes of this Act, such recommendation to be accompanied by a report on the size, location, and cost of the proposed plant and the engineering and economic details with respect thereto;

“(d) study methods for the recovery and marketing of commercially valuable byproducts resulting from the conversion of saline water; and

“(e) undertake economic studies and surveys to determine present and prospective costs of producing water for beneficial consumptive purposes in various parts of the United States by the leading saline water processes as compared with other standard methods.

“SEC. 3. In carrying out his functions under section 2 of this Act, the Secretary may—

“(a) acquire the services of chemists, physicists, engineers, and other personnel by contract or otherwise;

“(b) enter into contracts with educational institutions, scientific organizations, and industrial and engineering firms;

“(c) make research and training grants;

“(d) utilize the facilities of Federal scientific laboratories.

“(e) establish and operate necessary facilities and test sites at which to carry on the continuous research, testing, development, and programming necessary to effectuate the purposes of this Act;

“(f) acquire secret processes, technical data, inventions, patent applications, patents, licenses, land and interests in land (including water rights), plants and facilities, and other property or rights by purchase, license, lease, or donation;

“(g) assemble and maintain pertinent and current scientific literature, both domestic and foreign, and issue bibliographical data with respect thereto;

“(h) cause on-site inspections to be made of promising projects, domestic and foreign, and, in the case of projects located in the United States, cooperate and participate in their development in instances in which the purposes of this Act will be served thereby;

“(i) foster and participate in regional, national, and international conferences relating to saline water conversion;

“(j) coordinate, correlate, and publish information with a view to advancing the development of low-cost saline water conversion projects; and

“(k) cooperate with other Federal departments and agencies, with State and local departments, agencies, and instrumentalities, and with interested persons, firms, institutions, and organizations.

“SEC. 4. (a) Research and development activities undertaken by the Secretary shall be coordinated or conducted jointly with the Department of Defense to the end that developments under this Act which are primarily of a civil nature will contribute to the defense of

the Nation and that developments which are primarily of a military nature will, to the greatest practicable extent compatible with military and security requirements, be available to advance the purposes of this Act and to strengthen the civil economy of the Nation. The fullest cooperation by and with Atomic Energy Commission, the Department of Health, Education, and Welfare, the Department of State, and other concerned agencies shall also be carried out in the interest of achieving the objectives of this Act.

“(b) All research within the United States contracted for, sponsored, cosponsored, or authorized under authority of this Act, shall be provided for in such manner that all information, uses, products, processes, patents, and other developments resulting from such research developed by Government expenditure will (with such exceptions and limitations, if any, as the Secretary may find to be necessary in the interest of national defense) be available to the general public. This subsection shall not be so construed as to deprive the owner of any background patent relating thereto of such rights as he may have thereunder.

“SEC. 5. (a) The Secretary may dispose of water and byproducts, resulting from his operations under this Act. All moneys received from dispositions under this section shall be paid into the Treasury as miscellaneous receipts.

“(b) Nothing in this Act shall be construed to alter existing law with respect to the ownership and control of water.

“SEC. 6. The Secretary shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act and of prospective action during the ensuing year.

“SEC. 7. The Secretary of the Interior may issue rules and regulations to effectuate the purposes of this Act.

“SEC. 8. There are authorized to be appropriated such sums, to remain available until expended, as may be necessary, but not more than ~~[\$75,000,000]~~ \$275,000,000 in all, (a) to carry out the provisions of this Act during the fiscal years 1962 to ~~[1967]~~ 1972, inclusive; (b) to finance, for not more than two years beyond the end of said period, such grants, contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act; and (c) to finance, for not more than three years beyond the end of said period, such activities as are required to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act: *Provided*, That funds available in any one year for research and development may, subject to the approval of the Secretary of State to assure that such activities are consistent with the foreign policy objectives of the United States, be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That every such contract or agreement made with any public or private agency in a foreign country shall contain provisions effective to insure that the results or information developed in connection therewith shall be available without cost to the United States for the use of the United States throughout the world and for the use of the general public within the United States.”

SEC. 2. Section 4 of the joint resolution of September 2, 1958 (72 Stat. 1707; 42 U.S.C. 1958(d)), is hereby amended to read:

"The authority of the Secretary of the Interior under this joint resolution to construct, operate, and maintain demonstration plants shall terminate upon the expiration of twelve years after the date on which this joint resolution is approved. Upon the expiration of a period deemed adequate for demonstration purposes for each plant, but not to exceed such twelve-year period, the Secretary shall proceed as promptly as practicable to dispose of any plants so constructed by sale to the highest bidder, or as may otherwise be directed by Act of Congress. Upon such sale, there shall be returned to any State or public agency which has contributed financial assistance under section 3 of this joint resolution a proper share of the net proceeds of the sale."

Approved September 22, 1961.



Calendar No. 307

89TH CONGRESS
1ST SESSION

S. 24

[Report No. 319]

IN THE SENATE OF THE UNITED STATES

JANUARY 6, 1965

Mr. ANDERSON (for himself, Mr. BARTLETT, Mr. BIBLE, Mr. LONG of Missouri, Mr. MOSS, Mr. TOWER, and Mr. YARBOROUGH) introduced the following bill; which was read twice and referred to the Committee on Interior and Insular Affairs

JUNE 14, 1965

Reported by Mr. ANDERSON, without amendment

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That in order to expand, extend, and accelerate the saline
4 water conversion program conducted by the Secretary of the
5 Interior, the Act of September 22, 1961 (75 Stat. 628), is
6 hereby amended as follows:

7 (1) In section 2 (b) add the words “, module, compo-
8 nent,” after the word “laboratory.”

9 (2) In section 8 substitute the figure “\$275,000,000”

89TH CONGRESS
1ST SESSION

S. 24

[Report No. 319]

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

By Mr. ANDERSON, Mr. BARTLETT, Mr. BIBLE,
Mr. LONG of Missouri, Mr. MOSS, Mr. TOWER,
and Mr. YARBOROUGH

JANUARY 6, 1965

Read twice and referred to the Committee on Interior
and Insular Affairs

JUNE 14, 1965

Reported without amendment

1 for the figure “\$75,000,000” and the figure “1972” for the
2 figure “1967”.

A BILL

TO

FOR

Digest of CONGRESSIONAL PROCEEDINGS

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. 20250

Official Business

Postage and Fees Paid

U. S. Department of Agriculture

OFFICE OF
BUDGET AND FINANCE

(For information only;
should not be quoted
or cited)

Issued June 17, 1965

For actions of June 16, 1965

89th-1st; No. 109

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HIGHLIGHTS: House passed bill to establish Dept. of Housing and Urban Development. House Rules Committee cleared omnibus housing bill including title on rural housing. Senate passed cigarette labeling bill. Senate passed bill to expand salt-water research program.

SENATE

1. CIGARETTE LABELING. Passed, 72-5, as reported S. 559, to provide for regulation of labeling of cigarettes so as to state that smoking may be a health hazard. pp. 13404-38, 13440-4
2. DEBT LIMIT. Passed, 61-26, without amendment H. R. 8464, providing for a 1-year increase in the public debt limit to \$328 billion. pp. 13394-7, 13399-404
This bill will now be sent to the President.
3. D. C. APPROPRIATION BILL. The Appropriations Committee reported with amendments this bill, H. R. 6453 (S. Rept. 333). p. 13361
4. RECREATION. The Interior and Insular Affairs Committee reported with amendments

S. 360, to provide for establishment of the Indiana Dunes National Lakeshore (S. Rept. 334). p. 13361

5. EXPORT CONTROL. Sen. Robertson said he plans to recommend passage of H. R. 7105, to extend the Export Control Act for 1 year without amendment, in view of the short time remaining before expiration of the Act. Such action would involve rejection of the McGovern amendment to change the requirement that half of our Public Law 480 wheat exports be in American vessels. p. 13370
6. ELECTRIFICATION. Passed with amendment S. 1761, to authorize a third power plant at the Grand Coulee Dam. pp. 13375-7
7. WATER. Sen. Ribicoff discussed and inserted an article analyzing the "debate" between those favoring more dams and those favoring preservation of natural beauty. pp. 13382-3
Passed without amendment S. 24, to authorize appropriation of \$200 million additional for the period ending with the fiscal year 1972, for salt-water research through the Interior Department. p. 13404
8. ECONOMIC SITUATION. Sen. Magnuson inserted an address by Secretary of Commerce Connor, "The Growing Economy." pp. 13385-6
9. POLLUTION. Sen. Byrd, W. Va., inserted his address favoring air and water pollution control. pp. 13386-8
10. INTERGOVERNMENTAL RELATIONS. Sen. Symington inserted Vice President Humphrey's speech on cooperative efforts at Federal and local levels. pp. 13392-4
11. FOREIGN AID. Sen. Harris charged that, while accepting our wheat shipments, UAR is exporting rice. p. 13394

HOUSE

12. HOUSING. The Rules Committee reported a resolution for the consideration of H. R. 7984, to assist in the provision of housing for low and moderate income families, to promote orderly urban development, to improve living environment in urban areas, and to extend and amend laws relating to housing, urban renewal, and community facilities (p. 13312). Title IX of this bill "would provide a new program of insured housing loans under the Farmers Home Administration to permit private capital to make mortgage financing available in rural and rural nonfarm areas.
Passed as reported H. R. 6927, to establish a Department of Housing and Urban Development. pp. 13286-304
13. TAXATION. Received the conference report on H. R. 8371, to reduce excise taxes (H. Rept. 525) (pp. 13354-8). Conferees were appointed earlier (p. 13304).
14. TREASURY, POST OFFICE, AND EXECUTIVE OFFICE APPROPRIATION BILL, 1966. Conferees were appointed on this bill, H. R. 7060. p. 13285
15. APPROPRIATIONS. The Appropriations Committee was granted permission to file, by midnight June 17, reports on Defense Department and public works appropriations, 1966. pp. 13285-6

on the fiscal policies of this Government at this time by starting a quorum call and then running through a vote to increase the national debt without having a ye-a-and-nay vote.

I am not reproaching anyone or saying that there was any deceit or trickery about it. I am willing to say that perhaps the Senator from New Hampshire should have understood that he must be here and demand a ye-a-and-nay vote. I never dreamed that that was necessary. While I remain a Member of this body, if I am alive, well, and have a voice to speak, there never will be another increase in the debt ceiling without a vote.

Mr. DIRKSEN. Mr. President, I could not even find any Senators to take time on the bill. I took most of the time. Then there was a small amount of discussion on other subjects. I had to surrender the time on which we had agreed. I went to both sides and said, "Who wants a ye-a-and-nay vote?" I cannot be chasing Senators all over the Capitol. But to those who were present I said, "Do you wish a ye-a-and-nay vote? If so, you will have it. I shall get a sufficient number of Senators in the Chamber to get a show of hands and we shall have a ye-a-and-nay vote." But I found no takers.

Mr. COTTON. Mr. President, will the Senator yield?

Mr. MANSFIELD. I yield.

Mr. COTTON. No Member of this body is more fair and square in dealings with Senators than both the majority leader and the minority leader. I have never asked anything from the distinguished minority leader which was in his power to give me, in courtesy and kindness, that he has not given to me.

Mr. DIRKSEN. And I shall always try to do so.

Mr. COTTON. I know that and appreciate it. However, with as alert, wise, and penetrating a mind as has the distinguished minority leader, since I came to him last night and told him that I would take the floor and fight against putting through as an amendment to the tax bill, that everyone intended to vote for, as significant a measure as the proposed increase in the debt ceiling, I would have thought that he might have known that I desired an opportunity to vote against the bill. I did not want to speak on the subject.

Mr. MANSFIELD. Mr. President, will the Senator yield? I believe the best way to bring the issue to a head is to ask unanimous-consent to reconsider the bill, and I intend to do so.

Mr. COTTON. May I complete my sentence?

Mr. MANSFIELD. Surely.

Mr. COTTON. I did not wish an opportunity to speak against the bill because I realize that there is no chance to defeat it. I have never made a practice of taking the time of the Senate with useless remarks. I merely wished an opportunity to cast a protest vote.

Mr. DIRKSEN. To complete the record, what the distinguished Senator from New Hampshire has said is exactly correct. I scurried around the Senate Chamber to make sure that the two bills would be separated. But I did not know

that the Senator had in mind a ye-a-and-nay vote on the debt ceiling bill. That results from the obtuseness and the lack of ready wit on the part of the minority leader, for which I apologize.

Mr. MANSFIELD. The Senator from New Hampshire was on the floor of the Senate and happened to leave around that time. It was purely coincidental.

Mr. President, I shall ask unanimous consent to reconsider the vote by which the bill (H.R. 8464) was passed. I believe that we are wasting too much time talking about a vote that we did not have.

Mr. WILLIAMS of Delaware. Mr. President, I recognize the importance of the bill, but I should like to point out that last night, when the Senate decided to cut taxes by \$4.8 billion, it made the decision as to whether the debt ceiling would be raised. When the Secretary of the Treasury was before the committee he confirmed, to put it in blunt words, that the increase was necessary to finance the tax cut. If Congress rejects the proposed increase in the debt ceiling, I do not believe that the President would have any choice but to veto the tax cut that the Senate voted last night. Recognizing that point, I voted against the tax cut yesterday because I think it is unwise to cut taxes and finance the reduction on borrowed money, which is exactly what we are doing here today. We are raising the debt ceiling by \$4 billion so that we can finance yesterday's tax cut.

Mr. President, I also voted against the tax cut. I shall now vote against increasing the debt ceiling, recognizing that if we defeat the proposed increase in the debt ceiling, we shall defeat a tax cut which in my opinion should have been postponed until we had a balanced budget. Let us balance the budget first before we start talking about cutting taxes. But let us get straight what we are doing. We cannot have our cake and eat it, too.

Mr. MANSFIELD. Mr. President, I ask unanimous consent to reconsider the vote by which the bill (H.R. 8464) was passed, notwithstanding the fact that a motion to reconsider has already been tabled.

Mr. BASS. Mr. President, reserving the right to object, I understand that further consideration of the bill must be by unanimous consent.

The PRESIDING OFFICER. The Senator is correct.

Mr. BASS. I point out that the Senator in charge of the bill has left the floor of the Senate.

Mr. MANSFIELD. That is all right. He understands.

Mr. BASS. Does he understand?

Mr. MANSFIELD. Yes.

Mr. BASS. Will the vote be taken immediately or will further debate be in order?

Mr. MANSFIELD. The vote will be taken immediately.

Mr. BASS. If the majority leader will include in his request that the vote is to be taken immediately, I shall withdraw my reservation of objection.

Mr. MANSFIELD. The vote will take place immediately because all time has been yielded back or used.

The PRESIDING OFFICER. Is there objection to the request of the Senator from Montana?

Mr. BASS. Mr. President, I withdraw my reservation of objection.

The PRESIDING OFFICER. If there be no objection, the request of the Senator from Montana is agreed to.

The yeas and nays were ordered.

Mr. MANSFIELD. Mr. President, a parliamentary inquiry.

The PRESIDING OFFICER. The Senator will state it.

Mr. MANSFIELD. The vote is now on passage of the bill providing for an increase in the debt ceiling limit.

The PRESIDING OFFICER. That is correct. The bill having been read the third time, the question is, Shall it pass? All time has been yielded back. On this question the yeas and nays have been ordered, and the clerk will call the roll.

Mr. LONG of Louisiana. I announce that the Senator from Alaska [Mr. GRUENING], the Senator from Michigan [Mr. HART], the Senator from Utah [Mr. MOSS], the Senator from Michigan [Mr. McNAMARA], the Senator from Maine [Mr. MUSKIE], and the Senator from Georgia [Mr. TALMADGE] are absent on official business.

I further announce that the Senator from Wyoming [Mr. McGEE], the Senator from Georgia [Mr. RUSSELL], and the Senator from Texas [Mr. YARBOROUGH] are necessarily absent.

I further announce that, if present and voting, the Senator from Alaska [Mr. GRUENING], the Senator from Wyoming [Mr. McGEE], the Senator from Michigan [Mr. McNAMARA], and the Senator from Texas [Mr. YARBOROUGH] would each vote "yea."

Mr. KUCHEL. I announce that the Senator from Hawaii [Mr. FONG] and the Senator from Vermont [Mr. PROUTY] are absent on official business.

The Senator from New York [Mr. JAVITS] is necessarily absent, and if present and voting, would vote "yea."

The Senator from Kansas [Mr. PEARSON] is absent on official committee business.

On this vote, the Senator from Hawaii [Mr. FONG] is paired with the Senator from Kansas [Mr. PEARSON]. If present and voting, the Senator from Hawaii would vote "yea" and the Senator from Kansas would vote "nay."

The result was announced—yeas 61, nays 26, as follows:

[No. 139 Leg.]

YEAS—61

Aiken	Gore	Morse
Anderson	Harris	Morton
Bartlett	Hartke	Nelson
Bass	Hayden	Neuberger
Bayh	Hill	Pastore
Bennett	Inouye	Pell
Bible	Jackson	Randolph
Boggs	Kennedy, Mass.	Ribicoff
Brewster	Kennedy, N.Y.	Russell, S.C.
Burdick	Kuchel	Saltonstall
Byrd, W. Va.	Long, Mo.	Scott
Cannon	Long, La.	Smathers
Carlson	Magnuson	Smith
Case	Mansfield	Sparkman
Church	McCarthy	Stennis
Clark	McGovern	Symington
Cooper	McIntyre	Tydings
Dirksen	Metcalf	Williams, N.J.
Dodd	Mondale	Young, Ohio
Douglas	Monroney	
Fulbright	Montoya	

NAYS—26

Allott	Hickenlooper	Murphy
Byrd, Va.	Holland	Proxmire
Cotton	Hruska	Robertson
Curtis	Jordan, N.C.	Simpson
Dominick	Jordan, Idaho	Thurmond
Eastland	Lausche	Tower
Ellender	McClellan	Williams, Del.
Ervin	Miller	Young, N. Dak.
Fannin	Mundt	

NOT VOTING—13

Fong	McNamara	Russell, Ga.
Gruening	Moss	Tammage
Hart	Muskie	Yarborough
Javits	Pearson	
McGee	Prouty	

So the bill (H.R. 8464) was passed.

EXPANSION OF SALINE WATER
CONVERSION PROGRAM

Mr. MANSFIELD. Mr. President, I move that the Senate proceed to the consideration of Calendar No. 307, S. 24.

The PRESIDING OFFICER. The clerk will state the bill by title.

The LEGISLATIVE CLERK. A bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

The PRESIDING OFFICER. The question is on agreeing to the motion of the Senator from Montana.

The motion was agreed to; and the Senate proceeded to consider the bill.

Mr. ANDERSON. Mr. President, it is with a great deal of satisfaction that I support S. 24, the bill now before the Senate to extend and accelerate the saline water conversion program. As my colleagues in the Senate know, this is a program in which I have had a great interest for a long time. It was my privilege to introduce the present bill which was submitted and endorsed specifically by the President of the United States. The bill expands the present Federal program for research and development in the field of saline water conversion by authorizing an additional \$200 million of appropriations for the period ending in fiscal year 1972. Much progress has been accomplished in the past 5 years during which the Federal Government has been operating under the Anderson-Aspinall Act of 1961. However, this year the President personally had a hand in reorganizing the Office of Saline Water in the Department of the Interior. The new Director is Mr. Frank DiLuzio, a man for whose ability and competence the senior Senator from New Mexico has a great deal of respect. This has come from a long personal association during the last 2 years of which Mr. DiLuzio served as the top staff officer on the Senate Committee on Aeronautical and Space Sciences. In addition to my high esteem for his professional ability, I regard him with a great deal of personal affection and admiration.

The reason our committee unanimously reported this bill for the full amount requested by the President stemmed from our confidence not only in the officials directing the program but in our belief that the program is so important to the future of our country that it warrants our full and wholehearted support.

In passing this bill, we are not issuing a blank check to the Department of the Interior to disburse \$200 million. In fact Chairman Jackson of the Interior and Insular Affairs Committee is inaugurating a policy of requiring at least annual hearings into the state and progress of our desalination program. This thorough congressional review by the committee with legislative oversight responsibility for this program will keep Congress and the American people fully apprized of developments in this important area. In view of these two reasons: First, the new leadership at the helm of the program, and second, the guarantee of close congressional review and oversight of the program, I wholeheartedly endorse this bill and commend it to my colleagues.

I urge its speedy enactment in order that appropriate planning for the future of the program can continue.

The PRESIDING OFFICER. The bill is open to amendment. If there be no amendment to be proposed, the question is on the engrossment and third reading of the bill.

The bill was ordered to be engrossed for a third reading, was read the third time, and passed, as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words " , module, component," after the word "laboratory."

(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,000,000" and the figure "1972" for the figure "1967".

Mr. MANSFIELD. Mr. President, I ask unanimous consent to have printed in the RECORD an excerpt from the report (No. 319), explaining the purposes of the bill.

There being no objection, the excerpt was ordered to be printed in the RECORD, as follows:

PURPOSE OF THE BILL

The purpose of S. 24 is to provide for an expansion of the Federal program of research and development in the field of saline water conversion, through authorization of an additional \$200 million of appropriations for the period ending fiscal year 1972. Under the existing program, the technology of water desalting has been advanced to the point where it promises that fresh water can be produced from the sea in large combined distillation and electric power generating plants at a cost estimated at 30 to 35 cents per thousand gallons of water, and about 3 mills per kilowatt-hour for electric power. Such costs for water, however, can only be achieved by the construction of a desalting plant about 100 times larger than any yet constructed. Such an increase in size over existing plants presents a number of engineering challenges that must be overcome before an actual operating plant can be shown to be feasible for meeting actual needs.

Substantial investments in engineering and testing of large-scale components, modules, or sections of plants will be required to show that the distillation process will actually produce the results calculated. In addition, an increase in the scale of research and development work on other desalting and demineralizing processes is desirable at this time to

develop techniques that will be useful in dealing with a number of water problems in the inland parts of the Nation.

S. 24 will permit roughly a fourfold expansion of the research program. It is intended to lead, within the next few years, to recommendations for the construction of one or more large-scale desalting plants that can fill a real need through the production of water for the growing population and industry of America.

MESSAGE FROM THE HOUSE

A message from the House of Representatives, by Mr. Bartlett, one of its reading clerks, announced that the House had disagreed to the amendments of the Senate to the bill (H.R. 7060) making appropriations for the Treasury and Post Office Departments, the Executive Office of the President, and certain independent agencies for the fiscal year ending June 30, 1966, and for other purposes; agreed to the conference asked by the Senate on the disagreeing votes of the two Houses thereon, and that Mr. STEED, Mr. PASSMAN, Mr. ADDABBO, Mr. MAHON, Mr. CONTE, Mr. ROBISON, and Mr. JONAS were appointed managers on the part of the House at the conference.

ENROLLED BILLS SIGNED

The message also announced that the Speaker had affixed his signature to the following enrolled bills, and they were signed by the Vice President:

S. 856. An act for the relief of the estate of R. M. Clark; and

S. 2089. An act to provide assistance to the States of California, Oregon, Washington, Nevada, and Idaho for the reconstruction of areas damaged by recent floods and high waters.

LABELING OF CIGARETTES

Mr. MANSFIELD. Mr. President, I ask unanimous consent that the Senate proceed to the consideration of Calendar No. 181, S. 559.

The PRESIDING OFFICER. The clerk will state the bill by title.

The LEGISLATIVE CLERK. A bill (S. 559) to regulate the labeling of cigarettes, and for other purposes.

The PRESIDING OFFICER. Is there objection to the present consideration of the bill?

There being no objection, the Senate proceeded to consider the bill (S. 559) to regulate the labeling of cigarettes and for other purposes, which had been reported from the Committee on Commerce with amendments.

UNANIMOUS-CONSENT AGREEMENT

Mr. MANSFIELD. Mr. President, I believe that I have discussed this with most, if not all, of the interested Senators. I ask unanimous consent that, on the pending legislation, there be a 3-hour limitation, including amendments, 1½ hours to be under the control of the distinguished Senator from Oregon [Mrs. NEUBERGER] and 1½ hours to be under the control of the distinguished Senator from Kentucky [Mr. MORTON], and that paragraph 3 of rule XII, requiring a quorum call for this purpose be suspended.

S. 24

IN THE HOUSE OF REPRESENTATIVES

JUNE 17, 1965

Referred to the Committee on Interior and Insular Affairs

AN ACT

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 That in order to expand, extend, and accelerate the saline
4 water conversion program conducted by the Secretary of the
5 Interior, the Act of September 22, 1961 (75 Stat. 628), is
6 hereby amended as follows:

7 (1) In section 2 (b) add the words “, module, compo-
8 nent,” after the word “laboratory.”

9 (2) In section 8 substitute the figure “\$275,000,000”
10 for the figure “\$75,000,000” and the figure “1972” for the
11 figure “1967”.

Passed the Senate June 16, 1965.

Attest:

FELTON M. JOHNSTON,

Secretary.

89TH CONGRESS
1ST SESSION

S. 24

AN ACT

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

JUNE 17, 1965

Referred to the Committee on Interior and Insular
Affairs

DIGEST of Congressional Proceedings

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C. 20250
OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF AGRICULTURE

OFFICE OF BUDGET AND FINANCE
FOR INFORMATION ONLY;
(NOT TO BE QUOTED OR CITED)

Issued June 25, 1965
For actions of June 24, 1965
89th-1st; No. 114

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HIGHLIGHTS: House committee approved cropland adjustment title of farm bill. Both Houses passed bill to continue Area Redevelopment Act 2 months. Senate committee voted to report housing bill. Senate subcommittee approved bill to establish Department of Housing and Urban Development.

SENATE

- 1. AREA REDEVELOPMENT.** Both Houses passed without amendment H. J. Res. 541, to continue for 2 months (through Aug. 31) the Area Redevelopment Act. This measure will now be sent to the President. pp. 14131, 14182-91
- 2. HOUSING.** The Banking and Currency Committee voted to report (on June 28) "an original bill embodying a proposed Housing and Urban Development Act of 1965." p. D571
A subcommittee of the Government Operations Committee approved S. 1599, to establish a Department of Housing and Urban Development. p. D572
- 3. RECLAMATION.** Considered S. 602, to expand the scope of the Small Reclamation Projects Act. The Congressional Record states that the bill was passed. However, the majority leader and the Daily Digest state that it will be considered further today. pp. 14152-4, D571

4. ADMINISTRATION. The Government Operations Committee submitted a report on a study of activities relating to inter-agency coordination, economy, and efficiency (S. Rept. 369). p. 14155
5. LEGISLATIVE PROGRAM. In addition to the small reclamation projects bill, the majority leader stated that today (or soon) the Senate would also consider several bills including the one on export control, that the military construction bill will come up Mon., and that the Senate may meet early on some days next week so it may take the long July 4 weekend recess. pp. 14154, D571

HOUSE

6. TREASURY, POST OFFICE, AND EXECUTIVE OFFICE APPROPRIATION BILL, 1966. Received the conference report on this bill, H. R. 7060 (H. Rept. 550). p. 14230
7. CROPLAND ADJUSTMENT. The Agriculture Committee "approved the cropland adjustment title on H. R. 7097," the farm bill. p. D573
8. FARM PROGRAM. Rep. Langer stated "millions of dollars of needed farm income have been lost to U. S. farmers as a result of CCC dumping," and inserted a task force statement on CCC resale prices. pp. 14215-16
9. EDUCATION. The Education and Labor Committee voted to report (but did not actually report) H. R. 9022, to provide financial assistance in the construction and operation of public elementary and secondary schools in areas affected by a major disaster, to eliminate inequities in the application of Public Law 815 in certain military base closings, and to make uniform eligibility requirements for school districts in Public Law 874. p. D573
The "Daily Digest" states that the Education and Labor Committee "adopted the subcommittee print on the higher education bill (H. R. 3220), as amended, a clean bill to be introduced." p. D574
10. WATER RESEARCH. A subcommittee of the Interior and Insular Affairs Committee voted to report to the full committee H. R. 7092 (amended), to expand, extend, and accelerate the saline water conversion program. p. D574
11. HIGHWAYS. The Public Works Committee voted to report (but did not actually report) H. R. 6790 (amended), to increase the limitation on emergency relief for the repair or reconstruction of highways under 23 U. S. C. 125. p. D574
12. FOREIGN AID. Reps. Halpern and Ottinger spoke against renewal of shipment of food to Egypt. pp. 14211-12, 14216
13. PERSONNEL; PAY. Rep. Gilbert spoke in support of the bill to adjust the salaries of postal and classified Federal employees and inserted his testimony before the subcommittee. pp. 14216-17
14. ECONOMIC POLICY. Rep. Boggs praised the economic growth and prosperity of the U. S. pp. 14219-27
15. LEGISLATIVE PROGRAM. Rep. Albert announced that on Mon. there will be a continuing resolution and that beginning Mon. the housing bill, the poverty bill, and the conference report on the Post Office and Treasury appropriation bill will be considered. p. 14209.
16. ADJOURNED until Mon., June 28. p. 14209

DIGEST of Congressional Proceedings

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C. 20250
OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF AGRICULTURE

OFFICE OF BUDGET AND FINANCE
FOR INFORMATION ONLY;
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Issued July 1, 1965
For actions of June 30, 1965
89th-1st; No. 118

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HIGHLIGHTS: House passed housing bill. Senate Committee voted to report USDA appropriation bill. House committee reported bill to postpone wheat referendum.

HOUSE

1. HOUSING LOANS. Passed, 245-169, with amendments H. R. 7984, the housing and urban development bill (pp. 14669-714). Agreed to an amendment by Rep. Hagen, Calif., to increase from 2,500 to 5,500 the population of a community which may be eligible for rural home loans through the Farmers Home Administration (pp. 14704-5). Title IX of the bill would provide a new \$300,000,000-per-year program of insured housing loans under the Farmers Home Administration in rural areas.
2. WHEAT. The Agriculture Committee reported without amendment H. R. 9477, to extend until not later than 30 days after adjournment of the current session of Congress the date for conducting the referendum with respect to the national marketing quota for wheat for the marketing year beginning July 1, 1966 (H. Rept. 571). p. 14764

3. EXPORT CONTROL. Concurred in the Senate amendments to H. R. 7105, to continue the Export Control Act for 4 years. This bill will now be sent to the President. p. 14716
4. SALT-WATER RESEARCH. The Interior and Insular Affairs Committee voted to report (but did not actually report), amended, H. R. 7092, to expand, extend, and accelerate the saline water conversion program of the Interior Department. p. D600
5. PUERTO RICO. The Interior and Insular Affairs Committee voted to report (but did not actually report) S. 2154, to amend the act establishing the Commission on the Status of Puerto Rico. p. D600
6. WATER RESOURCES. The conferees agreed to file (but did not actually file) a report on S. 21, the proposed Water Resources Planning Act. p. D601
7. TAXATION. The Judiciary Committee submitted a report on "State taxation of interstate commerce" (H. Rept. 565). p. 14764
8. D. C. APPROPRIATION BILL. Received the conference report on this bill, H. R. 6453 (H. Rept. 568). pp. 14762-3
9. BEEF EXPORTS. Rep. Olsen, Mont., reviewed and commended the efforts of producers, this Department, and others, to increase beef exports, stating that beef does not get its share of our export market. pp. 14761-2
10. FOREIGN AID. Rep. Ryan objected to wheat aid to Egypt. p. 14738
11. LABOR STANDARDS. Rep. Roosevelt inserted responses given the subcommittee by the Labor Department in the course of hearings on amendments to the Fair Labor Standards Act including data on wages paid for work relating to agriculture. pp. 14724-8
12. TARIFFS. Rep. Sikes spoke in favor of his bill to amend the Trade Expansion Act, stating that we should reshape our trade policy to support the better health of our economy. pp. 14738-9

SENATE

13. AGRICULTURAL APPROPRIATION BILL, 1966. The "Daily Digest" states that the Appropriation Committee voted to report (but did not actually report_ this bill H. R. 8370. p. D597
14. APPROPRIATIONS. The Appropriations Committee reported with amendments H. R. 7997 the independent offices appropriations bill, 1966, (S. Rept. 384). p. 14790
15. TRANSPORTATION. Passed as reported S. 1098, to amend the Interstate Commerce Act to insure the adequacy of the national railroad freight car supply (pp. 14827-9). This bill was earlier reported with amendment (S. Rept. 386) (p. 14790).
The Commerce Committee reported with amendments S. 1727, to provide for strengthening and improving the national transportation system (S. Rept. 387). p. 14791

DIGEST of Congressional Proceedings

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UNITED STATES DEPARTMENT OF AGRICULTURE
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HIGHLIGHTS: Senate committee reported bill to postpone wheat referendum. Sen. McGovern urged expanded food for peace program.

SENATE

1. WHEAT. The Agriculture and Forestry Committee reported without amendment H. R. 9497, to permit postponement of the wheat referendum until 30 days after the current session of Congress ends (S. Rcpt. 425). p. 15200
2. HEALTH. Continued debate on H. R. 6675, to provide a hospital insurance program for the aged under the Social Security Act with a supplementary health benefits program and an expanded program of medical assistance, to increase benefits under the Old-Age, Survivors, and Disability Insurance System, etc. pp. 15221-39, 15240-3, 15249-55, 15263-8, 15270-9
3. WATERSHEDS. The Agriculture and Forestry Committee approved plans for improvement on the following watershed projects: Crooked Creek, Ala.; Haney Creek, Ark., Upper Crooked Creek, Ark.; Muddy Fork of Silver Creek, Ind.; Assunpink

Creek, N. J.; St. Thomas-Lodema, N. Dak.; Buffalo Creek, O.; and Cub Creek, Nebr. p. D617

4. FOOD-FOR-PEACE. Sen. McGovern urged an expansion of the food-for-peace program and inserted an article stating that the "administration is seriously considering the possibility of using American agricultural productive capacity to meet world food needs." pp. 15279-80
5. APPROPRIATIONS. Sen. Hart submitted an amendment intended to be proposed to H. R. 8370, the agricultural appropriation bill for fiscal 1966. p. 15210
At the request of Sen. Mansfield, passed over H. R. 7997, the independent offices appropriation bill for fiscal 1966. p. 15196
6. TRANSPORTATION. At the request of Sen. Mansfield, passed over S. 1727, the omnibus transportation bill. p. 15196
7. HOUSING. Sen. Tower submitted amendments intended to be proposed to S. 2213, the housing and urban development bill. p. 15210
8. WATER POLLUTION. Sen. Boggs urged stricter control of water pollution at Federal installations and inserted an article on the subject. pp. 15213-4
9. SOIL AND WATER CONSERVATION. Sen. Mondale inserted his testimony before the Agriculture Subcommittee, Appropriations Committee, in support of additional funds for SCS soil and water conservation activities. pp. 15216-7
10. FARM CREDIT. Sen. Kuchel commended the Farm Credit Administration and the banks for cooperatives in aiding the nation's farmers, particularly in Calif. p. 15240
11. ECONOMIC OPPORTUNITY. Sen. Allott criticized a television broadcast on the work of the Office of Economic Opportunity. pp. 15243-6
12. ELECTRIFICATION. Sen. Miller praised the rural electric cooperatives in Iowa and inserted an article. pp. 15246-7
Sen. Thurmond charged that Secretary of the Interior Udall was attempting to "have the FPC deny the Duke Power Co., a license to construct a \$700 million electric power complex" in S. C. and inserted several items on the matter. pp. 15255-63
13. FOREIGN TRADE. Sen. Miller inserted an article expressing concern over possible adverse effects of recent actions of the European Common Market on foreign trade, particularly in agricultural commodities. pp. 15248-9

HOUSE

14. SALINE WATER RESEARCH. The Interior and Insular Affairs Committee reported with amendments H. R. 7092, to expand, extend, and accelerate the saline water water conversion program (H. Rept. 594). p. 15193
15. HIGHWAYS. The Public Works Committee reported with amendment H. R. 6790, to increase the limitation on emergency relief for the repair or reconstruction of certain highways (H. Rept. 596). p. 15193

SALINE WATER CONVERSION PROGRAM

JULY 7, 1965.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. ROGERS of Texas, from the Committee on Interior and Insular Affairs, submitted the following

R E P O R T

[To accompany H.R. 7092]

The Committee on Interior and Insular Affairs, to whom was referred the bill (H.R. 7092) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, having considered the same, report favorably thereon with amendments and recommend that the bill do pass.

The amendments are as follows:

Page 1, lines 5 and 6, strike out "the Act of September 22, 1961 (75 Stat. 628), is hereby amended" and insert "the Act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951 et seq.), is hereby further amended".

Page 1, lines 9, 10, and 11, strike out all of paragraph (2) and insert in lieu thereof:

(2) In section 8 substitute the figure "\$85,000,000" for the figure "\$75,000,000".

H.R. 7092 was introduced by Chairman Aspinall. It was recommended to the Congress in a communication from President Johnson. H.R. 8320, an identical bill, was introduced by Mr. McDowell.

PURPOSE

The purpose of H.R. 7092, as amended by the committee, is to authorize the fiscal year 1967 program of the Office of Saline Water. This is accomplished by amending the act of July 3, 1952, as amended, to provide authority for the construction of "modules" and "components" as a part of the research and development program and by authorizing the appropriation of an additional \$10 million for carrying out the purposes of this program during fiscal year 1967.

HISTORY AND STATUS OF THE PRESENT PROGRAM

The activities of the Federal Government in the field of saline water conversion began in 1952 when Congress passed Public Law 448 of the 82d Congress (act of July 3, 1952) which is referred to as the Saline Water Act of 1952. This original act authorized the appropriation of \$2 million for a 5-year research program to be administered by the Secretary of the Interior. The stated objective of this program was to develop economically feasible processes for converting sea water and other saline water to fresh water of a quality suitable for municipal, industrial, agricultural and other beneficial purposes.

After the program had been in effect for 3 years, it became apparent that a 5-year program was not long enough to accomplish the objective and that the \$2 million authorized was not adequate for financing the research work. In addition, certain changes and expansion in the authority granted in the original act were needed. These needs led to the enactment in 1955 of Public Law 111, 84th Congress (act of June 29, 1955). Public Law 111 extended the period of research to 10 years and increased the amount authorized to be appropriated from \$2 million to \$10 million. It also authorized the use of the facilities of existing Federal scientific laboratories to conduct research and technical development work and provided for full cooperation with the Defense Department, the Atomic Energy Commission, and other Federal agencies.

In 1958, the Secretary's authority was again expanded by enactment of Public Law 85-883 (act of September 2, 1958) which authorized the construction and operation of not less than five experimental demonstration plants for the conversion of sea water and brackish water. This act provided for three sea water conversion plants to be located on the east coast, gulf coast, and west coast respectively, with two of the three plants to have a capacity each of at least 1 million gallons per day. The act provided, in addition, for two brackish water plants to be located in the Northern Great Plains area and in the arid area of the Southwest, with one of the plants designed to produce at least 250,000 gallons a day.

The first of the demonstration plants was constructed at Freeport, Tex. This is a long tube vertical evaporator designed for the conversion of 1 million gallons per day. The plant is presently in operation.

The second sea water conversion plant was constructed at Point Loma, near San Diego, Calif., to demonstrate the multistage flash distillation process. In February 1964, in the national interest, this plant was transferred to the Navy and moved to the Guantanamo Naval Base in Cuba. At the time of such transfer, the Point Loma plant was producing important favorable research data and major plant modifications had been proposed. The Office of Saline Water and the Secretary of the Interior have recommended that a new and improved plant be built to replace the Point Loma plant and this committee, after full hearings on the matter, has given its approval to the construction of the proposed advanced technology plant, referred to as San Diego No. 2, provided it is built in conjunction with and as a part of the proposed West Coast Test Center.

The other sea water conversion plant has been constructed at Wrightsville Beach, N.C., for demonstrating the freezing process. It is designed for a capacity of 250,000 gallons per day. Several

serious problems have been encountered in its operation as the research goes forward.

The first of the brackish water plants was constructed at Webster, S. Dak. It is a 250,000-gallon-per-day plant demonstrating the electrodialysis process. This has been and continues to be a successful operation producing valuable research data on membrane processes.

The second brackish water plant was constructed in Roswell, N. Mex., to demonstrate the vapor compression distillation method of conversion. The plant, designed to produce 1 million gallons per day, was completed in 1963 and is presently in operation.

The Secretary has the authority to operate these demonstration plants until September 2, 1970.

In 1961, the saline water research program was again extended and expanded by the so-called Anderson-Aspinall Act. This act of September 22, 1961 (Public Law 87-295), provided for the expenditure of \$75 million for the 6-year period fiscal year 1962 through fiscal year 1967. Emphasis of the expanded program was focused on basic research rather than on development work. While recognizing the need for pilot plants and demonstration plants as the program progressed, the predominant view of the committee at that time favored a program of broad basic research in the hope of a real breakthrough in the cost of desalination.

The acts hereinbefore referred to authorized a total appropriation of \$84.3 million for research and development and \$10 million plus operation and maintenance costs for the demonstration plants. Through fiscal year 1966, Congress has appropriated \$64.3 million for the research program and roughly \$17 million for the demonstration plant program, including about \$7.9 million of the \$10 million authorized for construction. Thus, of the amount authorized to be appropriated for the research program in the 1961 act, there is a balance of \$20 million available for fiscal year 1967. In addition, funds are available from the \$10 million authorization for constructing the San Diego No. 2 demonstration plant.

In July 1964, the President directed the Department of the Interior, in collaboration with the Atomic Energy Commission and in consultation with the Office of Science and Technology, to develop a plan for an aggressive and imaginative program to advance progress in large-scale desalting of sea water. The conclusions and recommendations resulting from the studies initiated under this direction from the President are set out in a report approved by the Secretary of the Interior and the Chairman of the Atomic Energy Commission on September 22, 1964, and submitted to the President on that date. The program recommended not only includes large-scale desalting of sea water but provides for improving other existing processes and for accelerating basic research to discover new techniques for desalination.

The recommendations of the Department of the Interior and the Atomic Energy Commission to the President were partially implemented by submission to the Congress of the legislation embodied in H.R. 7092

COMMITTEE HEARINGS

The Subcommittee on Irrigation and Reclamation held public hearings on May 20 and 21 on the legislation recommended by the President. Representatives of the administration presenting testimony in support of the legislation were Secretary of the Interior

Udall; Dr. Donald Hornig, Director, Office of Science and Technology and Science Adviser to the President; Commissioner James T. Ramey of the Atomic Energy Commission; and Mr. Frank C. Di Luzio, Director of the Office of Saline Water. The committee also received testimony from numerous representatives of industries which have done extensive research work in this field, either on their own or by participation in the Federal program. In addition, the committee received testimony from several internationally known scientists with long experience in this field. Two additional days of hearings in executive session were held to discuss with Director Di Luzio the details of the proposed 5-year, \$200 million program.

COMMITTEE AMENDMENT AND PROGRAM AUTHORIZED

The program presented to the committee by the Department of the Interior was in terms of goals which the Department hoped to attain during the 5-year period. The only breakdown of the \$200 million program dollarwise furnished by the Department was by categories. For instance, the major categories and the dollar assignment for the 5-year period are as follows:

Distillation Division-----	\$75, 760, 000
Membrane Division-----	26, 550, 000
Special Projects Division-----	26, 100, 000
Research-----	54, 000, 000

In discussing these categories with the subcommittee, Mr. Di Luzio was able to state in general what the Office of Saline Water had in mind and what it hoped to accomplish during the 5-year period but he was not able to lay out a detailed program. This is understandable and the committee has no criticism of the new Director. The committee considers that Director Di Luzio, since assuming responsibility for this important national program only 6 months ago, has done an excellent job of putting the program on a sound basis and establishing definite goals.

The committee, of course, understands that in this type of research program the direction which it must take in the future depends to a great extent upon the progress which is made and the results obtained as the research progresses. Of course, it is not possible at this time to set out a 5-year program showing in detail how available funds will be spent. At the same time, the committee must retain its legislative responsibility for establishing the guidelines and the direction which the program is to take at this critical stage when it is proposed to be greatly accelerated. The question of where Federal role and responsibility with respect to any particular saline water conversion process or method ends and local government and industry responsibility begins is of vital interest to the committee. The objective of the program must be only to advance the state of the art of desalination, and the responsibility of the Federal Government and the Office of Saline Water for any process or method of conversion should be concluded at the earliest possible stage in the development. The committee questions whether the proposed program is properly balanced between expenditures for discovering new desalting techniques and expenditures for large modules, components, and plants. The committee has the responsibility for assuring that the expenditures of the limited funds available for this program are fully justified and

are in line with expenditures for other water research which is just as important.

Because the committee is so interested in making this program a success and in accomplishing the program objective of providing truly low-cost desalination, it will not approve a blank check for \$200 million. It feels it must share the responsibility for determining how the funds authorized are to be used. The committee has therefore amended the bill so that, in effect, authority is provided only for a fiscal year 1967 program not exceeding \$30 million.

The committee recognizes the need for research and development work on parts or segmented pieces of a large plant and, therefore, has no objection to amending the basic act to include the words "module" and "component." At the same time, the committee shall insist upon being given an opportunity to review specific development work proposed under the expanded authority which the addition of these two words provides.

Information on the program of the Office of Saline Water for fiscal year 1967, which was furnished the committee and presented to the committee by Mr. Di Luzio, was in sufficient detail that the committee understands what is proposed to be accomplished. The preliminary program totaling \$29 million is comparable to the fiscal year 1966 program with a modest expansion in research and the inclusion of approximately \$5.5 million to initiate development work on a module for large plants. The program calls for the establishment during fiscal year 1967 of the West Coast Test Center.

The committee has examined the general research program that the Office of Saline Water has in mind pursuing in fiscal year 1967. It provides for an increase of about \$2 million over the fiscal year 1966 research program and will permit some new meritorious proposals and projects to be initiated.

With respect to the West Coast Test Center, the committee understands the need for establishing it at the earliest possible date so that items such as pumps, special control devices, and special equipment to be installed at the Test Center are available at the time they are expected to be needed under the research and development schedule that has been laid out. In addition, the construction of the multi-stage flash distillation plant (San Diego No. 2) which the committee has approved cannot go forward until the site for the Test Center is selected and installation work is initiated.

With respect to the construction of the first module, the committee would like to be advised at such time as a final decision is reached as to its size and total cost. The committee understands that approximately \$5.5 million of the \$29 million is for this purpose. While Mr. DiLuzio talked to the committee in terms of building a 17-million-gallon-per-day hydraulic system at a cost of \$7.5 million, he indicated, at the same time, that there was a possibility, based upon other studies and experiments presently underway and upon the operation of the San Diego No. 2 demonstration plant, that the 17-million-gallon-per-day module might be bypassed, going directly to 50 million gallons per day. Because of this present uncertainty and the large cost involved, the committee requests that it be advised at the time the final decision on this matter is made, that it be furnished detailed data related to the development of the module, and that construction not be undertaken until the committee has had an opportunity to

review the matter. This request is not intended to prohibit the preparation of designs.

COMMITTEE POSITION ON FUTURE PROGRAM

The committee has no objection to the Department of the Interior and the Office of Saline Water planning its fiscal year 1968 program, for purposes of presentation to the Congress, on the basis of the goals set out in the 5-year program presented in support of H.R. 7092. The committee recognizes the need for extending and expanding the program. The committee's objective and the President's objective are the same. The question is how best to accomplish the objective of the program with the funds which can be made available. The committee and the Congress have responsibilities which cannot be met, in the committee's view, by approving the legislation recommended by the President.

COMMITTEE'S RECOMMENDATION

The Committee on Interior and Insular Affairs of the House of Representatives recommends that H.R. 7092, as amended, be enacted.

EXECUTIVE COMMUNICATION

The President's message to Congress (H. Doc. 128) recommending the legislation embodied in H.R. 7092 follows:

THE WHITE HOUSE,
Washington, March 29, 1965.

HON. JOHN W. MCCORMACK,
Speaker of the House of Representatives,
Washington, D.C.

DEAR MR. SPEAKER: Past generations of Americans have been blessed with an abundance of sparkling, clean water. But in recent years we have become careless in our stewardship of this vital resource—polluting, wasting, and carelessly exploiting it.

Water shortages—real as well as prospective—already plague some regions of our land. Other areas and communities will soon be threatened. Yet, we must have an abundance of fresh water if we are to continue to grow and prosper.

Action to conserve what nature has so generously provided has often been inadequate and too late. We are determined not to make this mistake again. I have already pledged full support for cleaning up our rivers—and keeping them clean. We will continue to foster conservation by planning for the wisest possible use of all existing water supplies and by curbing and eliminating wasteful and uneconomic uses of water.

But these steps are not enough. New sources of supply at competitive costs are also required if we are to stay abreast of the evermounting demand for water. The seas around us offer an inexhaustible reservoir to help meet this need in coastal areas while vast quantities of brackish water are available to supplement the supplies of many inland

areas. We must spare no effort in learning how to desalt these waters economically.

For the past 12 years the United States has been engaged in a program of research and development which has brought desalting technology to a point where it shows promise of economic application in the future. To stimulate the translation of this promise into reality, I requested the Department of the Interior last July to develop, in close collaboration with the Atomic Energy Commission, a proposed program which would significantly advance large-scale desalting technology.

The resulting report entitled "Program for Advancing Desalting Technology" was completed promptly and released to the public on October 26, 1964. It recommended—and I am transmitting with this letter draft legislation to accomplish—expansion, extension, and acceleration of the salt water conversion research and development activities now being conducted by the Department of the Interior under authority of the Anderson-Aspinall Act of 1961.

This legislative proposal would increase by \$200 million the \$75 million appropriation authorization provided in the 1961 act and extend through 1972 the time during which the authorized funds would be available to support this important program. Enactment of this legislation is vital if the Department of the Interior is to mount and lead the substantial sustained effort necessary to achieve truly economical desalting of sea and brackish waters.

In the meantime, I have already transmitted to the Congress a request for a supplemental appropriation of \$3.9 million in 1965 to enable the Department, through a reorganized Office of Saline Water, to accelerate its research and development activities along the general lines outlined in the report mentioned above. Desalting activities will receive continuing emphasis in 1966. My budgetary recommendations to Congress for the coming fiscal year amount to \$29 million for the Office of Saline Water, more than double the amount appropriated for 1965.

By pressing ahead with a vigorous program of economic desalting to meet our ever-growing domestic needs for water, we will at the same time provide the technology which can be shared with other nations. This technology could prove to be the key that will unlock the door to economic growth for many of these nations.

It would be difficult to exaggerate the power for good, the palliative effect on age-old animosities and problems, that would result from providing an abundance of water in lands which, for countless generations, have known only shortage. To stimulate cooperation in the field with such great potential for the good of mankind, the United States will convoke a symposium of interested nations in October 1965 to exchange information on desalting technology.

In recommending this measure to the Congress, I wish to acknowledge the foresight of such able legislators as Clinton Anderson, Wayne Aspinall, and the late Clair Engle. Our

present efforts in desalting rest in substantial measure upon the sound foundation they laid and on which we intend to build. I earnestly hope that their leadership and the progress which it has inspired can be carried forward without interruption by the prompt enactment of the bill I am transmitting today.

Sincerely,

LYNDON B. JOHNSON.

A BILL To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words “, module, component,” after the word “laboratory”.

(2) In section 8 substitute the figure “\$275,000,000” for the figure “\$75,000,000” and the figure “1972” for the figure “1967”.

CHANGES IN EXISTING LAW

In compliance with clause 3 of rule XIII of the Rules of the House of Representatives, changes in existing law made by the bill, as reported, are shown as follows (existing law proposed to be omitted is enclosed in black brackets, new matter is printed in *italic*, existing law in which no change is proposed is shown in roman):

ACT OF JULY 3, 1952 (66 STAT. 328), AS AMENDED (42 U.S.C. 1951 ET SEQ.)

In view of the increasing shortage of usable surface and ground water in many parts of the Nation and the importance of finding new sources of supply to meet its present and future water needs, it is the policy of the Congress to provide for the development of practicable low-cost means for the large-scale production of water of a quality suitable for municipal, industrial, agricultural, and other beneficial consumptive uses from saline water, and for studies and research related thereto. As used in this Act, the term “saline water” includes sea water, brackish water, and other mineralized or chemically charged water, and the term “United States” extends to and includes the District of Columbia, the Commonwealth of Puerto Rico, and the territories and possessions of the United States.

SEC. 2. In order to accomplish the purposes of this Act, the Secretary of the Interior shall—

(a) conduct, encourage, and promote fundamental scientific research and basic studies to develop the best and most economical processes and methods for converting saline water into water suitable for beneficial consumptive purposes;

(b) conduct engineering research and technical development work to determine, by laboratory, *module, component*, and pilot

plant testing, the results of the research and studies aforesaid in order to develop processes and plant designs to the point where they can be demonstrated on a large and practical scale;

(c) recommend to the Congress from time to time authorization for construction and operation, or for participation in the construction and operation, of a demonstration plant for any process which he determines, on the basis of subsections (a) and (b) above, has great promise of accomplishing the purposes of this Act, such recommendation to be accompanied by a report on the size, location, and cost of the proposed plant and the engineering and economic details with respect thereto;

(d) study methods for the recovery and marketing of commercially valuable byproducts resulting from the conversion of saline water; and

(e) undertake economic studies and surveys to determine present and prospective costs of producing water for beneficial consumptive purposes in various parts of the United States by the leading saline water processes as compared with other standard methods.

SEC. 3. In carrying out his functions under section 2 of this Act, the Secretary may—

(a) acquire the services of chemists, physicists, engineers, and other personnel by contract or otherwise;

(b) enter into contracts with educational institutions, scientific organizations, and industrial and engineering firms;

(c) make research and training grants;

(d) utilize the facilities of Federal scientific laboratories;

(e) establish and operate necessary facilities and test sites at which to carry on the continuous research, testing, development, and programing necessary to effectuate the purposes of this Act;

(f) acquire secret processes, technical data, inventions, patent applications, patents, licenses, land and interests in land (including water rights), plants and facilities, and other property or rights by purchase, license, lease, or donation;

(g) assemble and maintain pertinent and current scientific literature, both domestic and foreign, and issue bibliographical data with respect thereto;

(h) cause on-site inspections to be made of promising projects, domestic and foreign, and, in the case of projects located in the United States, cooperate and participate in their development in instances in which the purposes of this Act will be served thereby;

(i) foster and participate in regional, national, and international conferences relating to saline water conversion;

(j) coordinate, correlate, and publish information with a view to advancing the development of low-cost saline water conversion projects; and

(k) cooperate with other Federal departments and agencies, with State and local departments, agencies, and instrumentalities, and with interested persons, firms, institutions, and organizations.

SEC. 4. (a) Research and development activities undertaken by the Secretary shall be coordinated or conducted jointly with the Department of Defense to the end that developments under this Act which are primarily of a civil nature will contribute to the defense of the Nation and that developments which are primarily of a military nature will, to the greatest practicable extent compatible with mili-

tary and security requirements, be available to advance the purposes of this Act and to strengthen the civil economy of the Nation. The fullest cooperation by and with Atomic Energy Commission, the Department of Health, Education, and Welfare, the Department of State, and other concerned agencies shall also be carried out in the interest of achieving the objectives of this Act.

(b) All research within the United States contracted for, sponsored, cosponsored, or authorized under authority of this Act, shall be provided for in such manner that all information, uses, products, processes, patents, and other developments resulting from such research developed by Government expenditure will (with such exceptions and limitations, if any, as the Secretary may find to be necessary in the interest of national defense) be available to the general public. This subsection shall not be so construed as to deprive the owner of any background patent relating thereto of such rights as he may have thereunder.

SEC. 5. (a) The Secretary may dispose of water and byproducts resulting from his operations under this Act. All moneys received from dispositions under this section shall be paid into the Treasury as miscellaneous receipts.

(b) Nothing in this Act shall be construed to alter existing law with respect to the ownership and control of water.

SEC. 6. The Secretary shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act and of prospective action during the ensuing year.

SEC. 7. The Secretary of the Interior may issue rules and regulations to effectuate the purposes of this Act.

SEC. 8. There are authorized to be appropriated such sums, to remain available until expended, as may be necessary, but not more than ~~[\$75,000,000]~~ \$85,000,000 in all, (a) to carry out the provisions of this Act during the fiscal years 1962 to 1967, inclusive; (b) to finance, for not more than two years beyond the end of said period, such grants contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act; and (c) to finance, for not more than three years beyond the end of said period, such activities as are required to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act: *Provided*, That funds available in any one year for research and development may, subject to the approval of the Secretary of State to assure that such activities are consistent with the foreign policy objectives of the United States, be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That every such contract or agreement made with any public or private agency in a foreign country shall contain provisions effective to insure that the results or information developed in connection therewith shall be available without cost to the United States for the use of the United States throughout the world and for the use of the general public within the United States.

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Union Calendar No. 277

89TH CONGRESS
1ST SESSION

H. R. 7092

[Report No. 594]

IN THE HOUSE OF REPRESENTATIVES

APRIL 5, 1965

Mr. ASPINALL introduced the following bill; which was referred to the Committee on Interior and Insular Affairs

JULY 7, 1965

Reported with amendments, committed to the Committee of the Whole House on the State of the Union, and ordered to be printed

[Omit the part struck through and insert the part printed in italic]

A BILL

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That in order to expand, extend, and accelerate the saline
4 water conversion program conducted by the Secretary of the
5 Interior, the Act of September 22, 1961 (~~75 Stat. 628~~), is
6 ~~hereby amended~~ *the Act of July 3, 1952 (66 Stat. 328), as*
7 *amended (42 U.S.C. 1951 et seq.), is hereby further*
8 *amended as follows:*

9 (1) In section 2 (b) add the words “, module, compo-
10 nent,” after the word “laboratory”.

1 ~~(2)~~ In section 8 substitute the figure “~~\$275,000,000~~”
 2 for the figure “\$75,000,000” and the figure “1972” for the
 3 figure “1967”.

4 (2) In section 8 substitute the figure “\$85,000,000” for
 5 the figure “\$75,000,000”.

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July 14, 1964

14. TRADING STAMPS; FOOD PRICES. Rep. Wolff announced that he intends to address the House on Wednesday on the relationship between trading stamps and food prices, and expressed the opinion that Congressmen should know more about the interdependence of food prices and the stamps in order to protect the consumer. p. 15837
 15. RECREATION. Passed under suspension of the rules H. R. 89, to authorize establishment of the Tocks Island National Recreation Area in Pa. and N. J. pp. 15786-92
Passed under suspension of the rules H. R. 797, to establish the Whiskeytown-Shasta-Trinity National Recreation Area, Calif. pp. 15792-7
 16. PUERTO RICO. Passed without amendment S. 2154, to extend the life of the Commission on the Status of Puerto Rico through Sept. 30, 1966, and increase its authorization (pp. 15757-8). This bill will now be sent to the President.
 17. HEALTH. Conferees were appointed on H. R. 6675, the so-called medicare bill (pp. 15767). Senate conferees have already been appointed.
 18. PATENTS. Concurred in Senate amendments to H. R. 4185, to increase the fees payable to the Patent Office and to expedite prosecution of patent applications (pp. 15767-8). This bill will now be sent to the President.
 19. SUMMER EMPLOYMENT; PERSONNEL. By a vote of 336 to 22, passed under suspension of the rules H. R. 242, to extend the apportionment requirement in the Civil Service Act to temporary summer employment. pp. 15768-73
 20. ATOMIC ENERGY; ELECTRIFICATION. By a vote of 216 to 139, rejected a motion to suspend the rules and pass H. R. 8856, to amend the Atomic Energy Act to clarify the intent of Congress regarding regulation of the sale, generation, or transmission of electric power produced through the use of nuclear facilities licensed by the Atomic Energy Commission. pp. 15761-7
 21. FISHERY LOANS. Passed, under suspension of the rules, S. 998, to extend the term during which the Secretary of the Interior is authorized to make fisheries loans under the Fish and Wildlife Act of 1956. pp. 15778-83
 22. SALINE WATER RESEARCH. Passed with amendment S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, after substituting the text of a similar bill, H. R. 7092. pp. 15815-7
 23. HIGHWAYS. H. R. 6790, to increase the limitation on emergency relief for the repair or reconstruction of certain highways, was recommitted to the Committee on Public Works. p. 15785
 24. FARM LABOR. Rep. Cohelan commended and inserted Labor Secretary Wirtz' speech which "has offered a number of important and constructive suggestions." pp. 15841-3
- ITEMS IN APPENDIX
25. POVERTY. Extension of remarks of Rep. McClory criticizing the administration's war on poverty program and inserting an article "War on Poverty Saps American Spirit." p. A3686
 26. RESEARCH. Rep. Reuss inserted an article summarizing the findings of a House Government Operations Subcommittee study of the effects of Federal research

grants on higher education. pp. A3686-8

27. WATER SYSTEMS. Rep. Schmidhauser inserted an article discussing rural community water needs and urging major Congressional action on this subject. p. A3688.

BILLS INTRODUCED

28. DISASTER INSURANCE. H. R. 9761 by Rep. Dole, to authorize a study of methods of helping to provide disaster insurance coverage and other financial assistance to victims of future natural disasters; to Banking and Currency Committee.
29. FLOOD CONTROL. H. R. 9765 by Rep. Hathaway, to authorize a flood control project on the upper St. John River; to Public Works Committee. Remarks of author pp. 15837-9
30. CREDIT. S. 2275 by Sen. Douglas, to assist in the promotion of economic stabilization by requiring the disclosure of finance charges in connection with extensions of credit; to Banking and Currency Committee. Remarks of author, pp. 15848-55
31. HEALTH. S. J. Res. 96 by Sen. Robertson, to establish an Advisory Commission on Health Research Activities; to Government Operations Committee. Remarks of author, p. 15855

BILL APPROVED BY THE PRESIDENT

32. WATER PROJECTS. S. 1229, to provide uniform policies with respect to recreation and fish-wildlife benefits and costs of Federal multi-purpose water resource projects. Approved July 9, 1965 (Public Law 89-72).

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COMMITTEE HEARINGS JULY 13:
Farm bill, H. Agriculture (exec).
Farm labor bills, S. Labor (public witnesses).
Foreign aid bill, conferees (exec).

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birth of these Presidents will always have both great historical significance and great attraction to Americans.

I also want to commend the author of the bill, Congressman SCHMIDHAUSER, in whose district the site will be located, for the very methodical, nonpolitical, and objective manner in which he has proceeded with this legislation. Shortly after the former President was laid to rest near West Branch, Mr. SCHMIDHAUSER proposed that there be an historic site established instead of merely a GSA operated monument or grounds as had been planned. Upon arriving in Washington in January, he sought the advice and co-operation of the Department of Interior in developing proper legislation and with their help did develop the proper kind of legislation. While some others tried to play politics with the proposal, Mr. SCHMIDHAUSER proceeded very objectively and methodically for it should be a bipartisan or nonpartisan matter. The site will belong to all the people. Congressman SCHMIDHAUSER, as the Representative of the district in which the site is located, obviously always was a key to passage of the proposal, and he kept his eye on the objective and has done his part to establish the proper kind of site for a former President of the United States. Following is an editorial from the West Branch Times of April 15, 1965, which expresses significant sentiment from the area of the site:

Since stories of Hoover Park have disappeared from the headlines lately, many of you are wondering what became of the drive for a National Historic Site here. And well you might, for it certainly vitally affects all of us in this area, though others may turn their interest on and off like the turning off a water tap.

Here I should like to state, that we are able to keep in close touch with the situation through the efforts, and interest of our First District Congressman, JOHN R. SCHMIDHAUSER.

Representative SCHMIDHAUSER has not yet introduced a bill into Congress regarding the park, and with adequate reason. But that he has been following the progress of the project more closely than many others who originally involved themselves in order to get the headlines, is obvious to me.

Congressman SCHMIDHAUSER has investigated the methods and policy of the project, and in spite of insinuations of an eastern Iowa daily that it has been a political football, it is only through his efforts that it has not.

Though Iowa's Senators have introduced a bill in the other House asking that the area be declared a national park site, Congressman SCHMIDHAUSER has, and is, holding out for a complete investigation of the needs of the area, including the local people, before he takes any steps in that direction. Furthermore, he has, and is, prodding the National Park Service into local consultations before any irreversible actions are taken. He has made one visit here from Washington, by the way, and will probably be in the area again for the Easter recess.

Though many of my friends on the other side of the political fence may razz me a little bit about this, I am going to express a personal feeling of gratitude to our Representative in the Congress of the United States, Congressman JOHN R. SCHMIDHAUSER, for the interest he has taken in West Branch.

The Congressman was the first to propose that the area be recognized for what it was, an area of great historical significance,

due to the fact that Mr. Hoover was not only born here, but chose to be buried here.

But the Congressman hasn't let it go at that; he has taken steps to see that the establishment of a national historic site here will be as painless as possible; interfere as little as possible with the day-to-day operations of our small community as we go about the business of making a living.

And after all, this is essential, isn't it? For though these events are of great historical significance, 99 1/4 percent of us have to go on making a living. We are happy to turn aside for such occasions as the commemorative stamp on August 10, and other events, but we do have to look to such things as the monthly bills, and the income tax, and who is going to support our school, and how much rent are we going to have to pay, and are the taxes on our homes going up again, and why. These are important considerations, even in a town with a historical background.

And let's face it; they are questions that are affected by the fact that a national historic site will be established here. A hundred years from now, we'll probably be proud of it, if we live; but that doesn't make taxes any easier to pay today.

So I say, thank you Congressman SCHMIDHAUSER, for remembering West Branch, even though the number of votes here are much smaller than the time you have spent on us would seem to justify.

The SPEAKER. The question is on the motion of the gentleman from Colorado that the House suspend the rules and pass the bill (H.R. 8111).

The question was taken, and (two-thirds having voted in favor thereof) the rules were suspended and the bill was passed.

The title of the bill was amended to read: "A bill to establish the Herbert Hoover National Historical Site in the State of Iowa."

A motion to reconsider was laid on the table.

SALINE WATER CONVERSION PROGRAM

Mr. ROGERS of Texas. Mr. Speaker, I move to suspend the rules and pass the bill (H.R. 7092) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, as amended.

The Clerk read as follows:

H.R. 7092

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951 et seq.), is hereby further amended as follows:

(1) In section 2(b) add the words " , module, component," after the word "laboratory".

(2) In section 8 substitute the figure "\$85,000,000" for the figure "\$75,000,000".

The SPEAKER. Is a second demanded?

Mr. SAYLOR. Mr. Speaker, I demand a second.

The SPEAKER. Without objection, a second will be considered as ordered.

There was no objection.

The SPEAKER. The question is on the motion of the gentleman from Texas

that the House suspend the rules and pass the bill H.R. 7092.

The question was taken; and (two-thirds having voted in favor thereof) the rules were suspended and the bill was passed.

Mr. ROGERS of Texas. Mr. Speaker, I ask unanimous consent for the immediate consideration of the bill S. 24, to expand, extend, and accelerate the salt water conversion program conducted by the Secretary of the Interior, and for other purposes, a similar bill to the one just passed.

The Clerk read the title of the bill.

The SPEAKER. Is there objection to the request of the gentleman from Texas?

There was no objection.

The Clerk read the bill, as follows:

S. 24

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of September 22, 1961 (75 Stat. 628), is hereby amended as follows:

(1) In section 2(b) add the words " , module, component," after the word "laboratory".

(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,000,000" and the figure "1972" for the figure "1967".

AMENDMENT OFFERED BY MR. ROGERS OF TEXAS

Mr. ROGERS of Texas. Mr. Speaker, I offer an amendment.

The Clerk read as follows:

Strike out all after the enacting clause of S. 24 and insert the provisions of H.R. 7092 as passed.

The amendment was agreed to.

The Senate bill was ordered to be read a third time, was read the third time, and passed, and a motion to reconsider was laid on the table.

A similar House bill (H.R. 7092) was laid on the table.

Mr. ASPINALL. Mr. Speaker, approval of H.R. 7092, as reported from the Interior and Insular Affairs Committee, will authorize the full program for saline water research and development recommended by the administration for fiscal year 1967. Thirty million dollars will be available for the program which, in its preliminary stage of development for fiscal 1967, totals \$29 million. Language changes in the basic act provide authority to initiate development work on a module for large plants, for which there is about \$5.5 million included in the \$29 million estimate.

Mr. Speaker, the President requested the Congress to approve a 5-year extension in the saline water conversion program and an additional \$200 million for research and development. Acceptance of the President's recommendation would have made available \$220 million for the 6-year period, fiscal year 1967 through fiscal year 1972. After 4 days of hearings and executive consideration, the committee concluded that the approval of the recommended legislation would mean surrendering important responsibilities of the committee and the Congress for this important national program. There are several important policy questions involved as the expanded

program unfolds during the next few years.

First, this program must be kept in line and consistent with other water resources research programs which are just as important. Also, there is the important matter of assuring a proper balance between basic research and development work. Of vital importance is the decision as to where the Federal role and responsibility ends with respect to any particular saline water process or method and local government and industry responsibility begins. Federal responsibility should be terminated at the earliest possible stage in development of any particular process, but the committee is not sure this will be accomplished if left completely to the discretion of the program administrators. In addition, the committee has responsibility for assuring that expenditure of the limited funds available for this program is fully justified.

My committee is still optimistic about accomplishing the program objective, set out in original act of 1952, of providing truly low-cost desalination. We do not want to see basic research neglected as a result of the so-called leap forward in big plant development. We support the appropriation of as much money as can be used for worthwhile research conducted by qualified scientists which may lead to discovering new desalting techniques.

In support of the legislation, the administration's program for the 5-year extension was in terms of goals, and the \$200 million could not be broken down for specific research and development work. This, of course, is understandable because the direction of this type of research program is determined to a great extent by the progress which is made and the results that are obtained as the research work goes forward. Therefore, the committee believes that the only way we in the Congress can meet our responsibilities is to review this program year by year and give approval on that basis. It is possible, for instance, that the large expenditures proposed for development of modules, components, and large plants could be of no value if the processes and methods involved are made obsolete by new discoveries.

This program started in the Congress and in my committee 13 years ago. We have reviewed the progress year by year since that date. It started out as a very modest research effort with only \$2 million authorized to be expended over a 5-year period. It was expanded to a \$10 million program for a 10-year period and then, in 1961, it was extended another 5 years with an additional \$75 million authorized to be appropriated. Congress also authorized the construction of five demonstration plants at an estimated cost of \$10 million. We have appropriated about \$72 million for the entire program in the last 13 years. Now it has been proposed that we spend \$220 million in the next 6 years with the major part to be spent on large plant development. We all agree that this program needs to be extended and expanded but, during this critical expansion period, it

is important that Congress exercise its responsibility for close oversight of the program and for determining how the funds made available are to be used.

Mr. ROOSEVELT. Mr. Speaker, I rise in support of H.R. 7092 to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior.

The 1963 Report to the President on Water Research by the Federal Council for Science and Technology identified the following regions within the United States where projected water requirements will be approaching the limits of available supplies by the year 2000: the Pacific Southwest, Upper Colorado Basin, Western Gulf, Upper Missouri, Rio Grande-Pecos Basins, and the Great Basin. In certain of these areas, particularly the Pacific Southwest, large quantities of additional water will be required well in advance of that year, if restrictions on economic development and population growth are to be averted.

Three distinct water-use areas can be identified in the Pacific Southwest. These are: First, southern California-coastal, where water is used primarily for municipal and industrial purposes; second, Arizona, where water is used for municipal, industrial, and agricultural purposes; and third, southern California-interior, where most of the available water is used for agriculture.

Our immediate concern in the desalting program is the need for municipal and industrial water. Most of this need arises in or near the coast. Moreover, large sea-water conversion plants are best adapted to coastal locations and should be located near major population and industrial centers.

Water-resource planners generally agree that major decisions on future water supply for the coastal areas of southern California should be made by the mid-seventies. Desalting plants, if the technology is sufficiently developed, could provide the most economical source of water for this area.

Much of the existing inland deficiency is being met by "mining" ground water. In the interior valleys of southern California and in Arizona, ground-water tables have dropped as much as several hundred feet and the situation is critical.

The Colorado River is the principal source of water supply for the entire Pacific Southwest region. At the present time, approximately 1,100,000 acre-feet of Colorado River water are delivered to the southern California coastal area annually. Desalting plants constructed on the coast could meet all or part of this demand, thereby physically freeing Colorado River water to meet municipal and industrial deficiencies of inland areas in the region if appropriate exchange arrangements were developed.

The proposed program is not based on any prediction that desalted water can be made economically attractive for agricultural uses. If the cost of desalting could be brought to a level which would make practical its use for irrigation and replenishing ground-water aquifers, obviously the requirements would be much greater.

The need for sustaining and increasing the Federal role in research and development of economical desalination plants is clear. But equally clear is the need for major metropolitan areas to expand their own energies, talents, and funds on the development of programs to meet their own critical water needs.

My own city of Los Angeles is a good example. As pointed out in the 1964 Report of the Interior Department to the President, it is an area whose water needs are so critical that the plans and programs to meet these needs must be effected without delay. Los Angeles must commit itself to the development of its own programs and its own plans.

This is not to say that Los Angeles, or any other city, should or could go it alone. But, I am frankly disappointed that the city of Los Angeles has not been more determined to meet this most critical problem with its own vigorous program. The city of Los Angeles cannot afford to wait for the Federal program. It must, now, undertake its own research and development program. That it should work closely with the Federal Government and the State is obvious. But it has a responsibility. And it must, as must all major metropolitan areas facing the same problem, recognize its independent responsibility and commit its many resources to meeting this responsibility.

Mr. Speaker, what I point out regarding my own city of Los Angeles is true of many cities. Indeed, it is also true of many needs for which the Federal Government has developed far-sighted programs. The Federal Government has acted; our great cities must now act. It is with this caveat that I urge the passage of H.R. 7092.

Mr. LINDSAY. Mr. Speaker, I should like to express my support for H.R. 7092, the bill which provides for additional funds for the Federal saline water conversion program. It is hoped that, with the added sums specified in this bill, further progress may be made in achieving an adequate water supply in this country.

As the population in this country continues to expand so, too, will the demand for water for both human and industrial consumption. In some areas of the country including New York City, where population density is great and because of drought and other factors, people are suffering from a lack of sufficient water reserves.

In view of the increasing shortage of usable surface and ground water in many parts of the Nation and the importance of finding new and economical sources of supply to meet present and future needs, it is essential that we provide funds for the development of methods that will insure a continuing and ample supply of water.

Since over 70 percent of the earth is covered with salt water, the oceans are a logical source toward which we may turn. But before this can be accomplished practically, a low-cost process must first be developed if the water shortage problem is to be solved. Science and technology must be provided

with sufficient funds to be able to evolve an inexpensive and suitable desalinization process.

Mr. Speaker, I reiterate my support for the bill and express the hope that the Federal saline water conversion program will be appropriated sufficient funds to make maximum advances in this area.

GENERAL LEAVE TO EXTEND

Mr. ROGERS of Texas. Mr. Speaker, I ask unanimous consent that all Members have 5 legislative days in which to extend their remarks on this legislation.

The SPEAKER. Is there objection to the request of the gentleman from Texas?

There was no objection.

WYOMING VOTING RIGHTS

(Mr. RONCALIO asked and was given permission to address the House for 1 minute.)

Mr. RONCALIO. Mr. Speaker, House approval of the voting rights bill marks the continuation of an old struggle to broaden suffrage and the beginning of a new era of nationwide support for the implementation of constitutional guarantees. In earning its designation as the Equality State, Wyoming has played a central part in the fight to extend suffrage, for it led the way toward the enfranchisement of women by being the first State to forbid the denial of voting rights on grounds of sex.

Wyoming has continued its tradition of equality, for the voting rights bill stands as a monument to the dedication of the late Reverend James J. Reeb, of Casper, Wyo., who gave his life while protesting the denial to others of their voting privileges. My vote in favor of this bill was cast to insure that the traditions of Wyoming would be perpetuated and that the work of such men as Reverend Reeb would not be in vain.

In this same spirit of progressing toward equal rights for all, many courageous and dedicated Congressmen who had opposed the Civil Rights Act of 1964, supported the voting rights bill of 1965.

Hopefully, this nationwide demand for enforcement of the 15th amendment to the Constitution signifies a new era of cooperation, rather than conflict, in the civil rights area. The overwhelming support for the bill stands as a mandate for peaceful compliance with its provisions. With its historical interest in broadening suffrage, Wyoming applauds the passage of the voting rights bill and welcomes the new era of nationwide endorsement of equality.

CAREER INCENTIVE FOR PROFESSIONALLY TRAINED OFFICERS OF THE ARMED FORCES

(Mr. LEGGETT asked and was given permission to address the House for 1 minute and to revise and extend his remarks.)

Mr. LEGGETT. Mr. Speaker, on Friday I introduced a long overdue bill, H.R. 9731, amending titles 10 and 37 of the

United States Code to correct certain inequities and to provide career incentives for professionally trained officers of all the uniformed services.

The constant and expensive turnover of all types of professional personnel impairs the efficiency of our Armed Forces. I am especially concerned about the retention and procurement problem we now have as it pertains to the Medical Service Corps of the Army and Navy, the Biomedical Sciences Corps of the Air Force, and to optometry officers in particular.

The retention rate for optometry officers who entered the service in the years 1960-61 is less than 28 percent. Information I have received from the schools and colleges of optometry indicates that we will be fortunate indeed if we can fill 60 percent of the anticipated vacancies in the Army, Navy, and Air Force from their graduating classes. If the same high quality care is to be established and maintained for our men and women in the Armed Forces as is available to their counterparts in civilian life, we should expand the number of optometry billets, slots and positions which are now listed as requirements by the three services.

A similar retention problem exists in relation to all professional officers whose military specialty, such as law, divinity, optometry or a science allied to medicine, requires graduate or professional training beyond the baccalaureate level as a precondition for appointment. As a matter of equity all of the professional categories should receive equal credit for grade, rank and promotion purposes according to the years of professional education required for them to practice their military specialties.

Under present law the young man who spends his time and money to obtain the additional professional education required for his military assignment is, by so doing, in a less favorable position than his contemporary who entered service immediately after receiving his baccalaureate degree. Because of this it is becoming increasingly difficult for the services to obtain qualified professional officer personnel. The pay and allowances for professional personnel are totally insufficient to effectively compete with the civilian industrial, scientific, and academic environments. The demand for the services of individuals earning master or Ph. D. degrees is increasingly ahead of the number available.

The only recourse to the present critical situation is for the Department of Defense to sponsor the required out-service, graduate education for selected commissioned members on active duty; a stop-gap measure that is expensive, detracts from the operating forces, and does not provide sufficient numbers to properly meet all professional requirements of the Department.

I strongly believe, and hope that my distinguished colleagues of this House concur with me, that, in those cases in which advanced education is a required criterion for appointment in the services of our country, the appointee should be

more adequately compensated for the additional time and expense incurred in obtaining his educational achievement by the granting of comparable constructive credit.

Existing regulations impose a penalty on an individual who obtains an advanced education at his own personal expense—he be a doctor, minister, lawyer, engineer, or scientist. This penalty is sufficiently severe to deter these highly qualified individuals from entering the military services.

The legislation I am introducing would eliminate this penalty and thereby encourage a greater number of professionally trained individuals to enter the uniformed services and remain on a career basis.

ALLEGED SAVINGS BY THE DEPARTMENT OF DEFENSE

(Mr. JONAS asked and was given permission to address the House for 1 minute and to revise and extend his remarks.)

Mr. JONAS. Mr. Speaker, a story in last Saturday's Washington Post reported that President Johnson had announced that the cost reduction program of the Department of Defense had saved the taxpayers \$4.6 billion during the past fiscal year.

Now I am all for saving taxpayers' money, and if the President will document this alleged saving in Defense Department spending for the past fiscal year, and if the documentation shows that these savings have been accomplished without any impairment of national defense, I will be the first to applaud the accomplishment.

But the savings claimed by the President do not show up in the report of the U.S. Treasury for the fiscal year ending June 30, 1965. That report shows that the Defense Department withdrew \$51.415 billion in cash from the U.S. Treasury during the year ending June 30, 1964. The corresponding withdrawals for the year ending June 30, 1965, as reported by the U.S. Treasury, were \$49.423 billion.

Thus it appears that cash withdrawals from the Treasury by the Defense Department during the last fiscal year were only \$1.992 billion less than withdrawals during the previous fiscal year.

The Washington Post further reported that the President announced he was sending to the Cabinet Mr. McNamara's report showing these savings. I would most respectfully request that he also send the report to Congress if the report documents alleged savings of \$4.6 billion, because I think it would be helpful to the Congress and to the country to reconcile his figures with those appearing in the statement of the U.S. Treasury dated June 30, 1965, which show that the Defense Department during the past fiscal year withdrew from the U.S. Treasury only approximately \$2 billion less than the same Department withdrew in the previous fiscal year, and for the country to know where the "savings" occurred.

JOINT UNITED STATES-JAPAN COMMITTEE ON TRADE AND ECONOMIC AFFAIRS

(Mr. HANNA asked and was given permission to address the House for 1 minute and to revise and extend his remarks and include extraneous matter.)

Mr. HANNA. Mr. Speaker, we have no better friend in the world today than our Pacific neighbor, Japan. It is a tribute to the peoples of both Japan and America that their nations, who only 20 years ago were bitter adversaries in a terrible war, are today the best of international friends. Certainly the Japanese people have earned our deepest respect, for through sheer courage, determination, and plain hard work, they have wrought a miracle of recovery that has rebuilt their nation into one of the greatest in the world, and they have managed to do so while still retaining the finest traditions of a very rich culture. It is therefore with great pleasure that I take this opportunity to welcome to Washington and to the United States the Japanese delegates to the fourth meeting of the Joint United States-Japan Committee on Trade and Economic Affairs. The delegation, comprised of some of Japan's most distinguished public servants, includes Mr. Etsusaburo Shiina, Minister for Foreign Affairs; Mr. Takeo Fukuda, Minister of Finance; Mr. Takeo Miki, Minister of International Trade and Industry; Mr. Eiichi Sakata, Minister of Agriculture and Forestry; Mr. Torata Nakamura, Minister of Transportation; Mr. Hisao Kodaira, Minister of Labor; Mr. Aichihiro Fujiyama, Director General of the Economic Planning Agency; and Mr. Ryugi Takeuchi, Japan's Ambassador to the United States. To these gentlemen we would all like to say, "Yookoso Irasshaimashita," which, I understand, means, "You are very welcome, we are delighted to have you."

As we are all well aware, the Joint United States-Japan Committee on Trade and Economic Affairs is a continuing consultative body for discussing the principal trade and economic affairs of the two countries. It was formed as the result of an agreement between our beloved late President, John F. Kennedy, and former Japanese Prime Minister Harato Ikeda during the latter's visit to this country in June of 1961. As stated in the exchange of notes establishing the Committee, its functions are:

1. To consider means of promoting economic collaboration between the two countries;
2. In particular, to exchange information and views on matters which might adversely affect the continued expansion of mutually profitable trade and on questions relating to the economic assistance programs of the two countries which require joint consideration;
3. To report to the respective Governments on such discussions in order that consideration may be given to measures deemed appropriate and necessary to eliminate conflict in the international economic policies of the two countries, to provide for a fuller measure of economic collaboration, and to encourage the flow of trade.

The Committee meets at least once a year, with the meeting place and chair-

manship alternating between the two countries. The American members of the Committee includes the Secretaries of State, the Treasury, the Interior, Agriculture, Commerce, and Labor. If there are no objections, Mr. Speaker, I will insert a copy of the agenda for this year's meeting into the RECORD at the end of my speech.

Formulation of this Committee has proved to be one of the most welcome diplomatic developments of recent years. Certainly it has been one of the most unique. For here are the principal political officials concerned with economic affairs from two of the world's great nations meeting to educate each other on their respective problems, both political and economic, and to obtain firsthand knowledge of the nature and dimensions of the United States-Japanese economic relationship, of the worldwide economic interests of the two countries, and of the major political considerations which affect their economic policies. Moreover, here is a working, continuing, institutionalized arrangement for seeing that two very good friends remain that way. It gives real substance to our stated policy of close consultation and cooperation between the two countries on matters of mutual concern. It also provides a means of overseeing and guiding lower level diplomatic efforts, and it establishes a basis for further consultations and future negotiations, through diplomatic channels, concerning specific economic and commercial issues. And, if we are to judge from the joint communiqués issued after each of the three previous meetings, the Committee has so far proved to be an unqualified success. Full and frank discussions among a wide range of high-level officials on both sides have bared the problems which exist both within and between our two countries. Where disagreements have arisen, each side at least has been fully exposed to the other's point of view.

At this rate of success, the Committee could perhaps develop into a model for the conduct of all bilateral diplomatic affairs. Be that as it may, it certainly has proved its value to our country and Japan, a value that was graphically demonstrated when the third meeting, which had originally been canceled because of the tragic death of President Kennedy, was rescheduled to late January of 1964 despite the heavy domestic demands on the time of both the Japanese and American participants.

Indeed, the establishment of this Cabinet-level committee reflects the great importance which both of our countries attach to our economic relations. And well it should. For Japan is unquestionably this Nation's most important overseas trading partner. We sell more goods to Japan than to any other country with the single exception of our continental neighbor, Canada. Last year's sales to Japan totaled almost \$2 billion. Correspondingly, Japan sells more to the United States than to any other without exception. Certainly, Japan stands far and away as the best customer for the goods of my own State of California, which, by the way, began leading the Nation in exports as of last

year. Conversely, Japan is California's biggest supplier, providing over a third of all of our local imports.

Of course, our economic relationship is not without problems. Japan, who must trade to survive, has at our request graciously imposed voluntary restraints upon her exports to this country, but is increasingly and understandably anxious to have those restraints relaxed. We, of course, must be concerned about our balance-of-payments situation. And then there are problems and disagreements over such things as air rights, fishing rights, and textiles. Certainly, these are important problems and we hope for their speedy elimination.

But the differences between our two countries are miniscule besides the great common interests which bind us together in a great Pacific partnership. We have a common interest in the liberalization and consequent expansion of world trade. Both nations firmly believe that increased trade means increased prosperity and a richer life for all people, not just Americans and Japanese. As President Kennedy once observed, "A rising tide lifts all the boats." And too, we have a common interest in close technical and scientific cooperation to effectively utilize the best minds of both nations in an age of technological advance. Together we must look to the future. Nowhere is this more apparent than in the field of oceanography: through cooperation between our two nations, the resources of the vast Pacific can be developed to meet the great needs of the future for food, for minerals, for fresh water. Most of all, we have a common interest in achieving those two great goals of mankind—peace and freedom. For without peace there can be none of the prosperity of which we speak and none of the progress. This is a fact poignantly real to America and Japan. But there can be no permanent peace until the aggressive drive of the Communists to enslave the free peoples in Asia has been stopped. Therefore, we have a common interest in the maintenance of strong independent and prosperous nations in the Pacific.

These common interests, heavily reinforced by the deep mutual respect of our respective peoples for each other, have provided a firm foundation for a fruitful partnership between two great Pacific democracies. As partners, we can work together to multiply our already many close ties and strengthen the bonds of a growing Pacific community of nations.

Thus, we bid our distinguished guests, leaders of Japan, a hearty welcome. We want them to know that they and their countrymen will always be welcome here and that our people and our Government truly care about their country, our great partner and good friend in the Pacific. We trust that they enjoyed shooting the rapids in the Grand Tetons with our Cabinet-level outdoorsman, the distinguished Secretary of the Interior, and hope that diplomatic waters will be as successfully negotiated in the coming week.

The agenda follows:

DIGEST of Congressional Proceedings

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

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HIGHLIGHTS; Senate debated housing bill, including title on rural housing. Senate agreed to conference report on water resources development bill. Rep. Cabel praised USDA inspection services.

SENATE

1. HOUSING LOANS. Began debate on S. 2213, on housing and urban redevelopment, including a title on rural housing loans (pp. 16132, 16137-42, 16149-90). Sen. Kuchel submitted, but later withdrew, a proposed amendment to provide that the terms "rural" and "rural area" mean any area, open country, place, town, village, or city having a population of 5,500 inhabitants or less that is not part of or associated with an urban area, after Sen. Sparkman assured him that this question would be considered by the conference committee (p. 16172). Agreed to a unanimous-consent agreement by Sen. Mansfield to limit further debate on the bill and amendments beginning Thurs., July 15 (p. 16185).
2. WATER RESOURCES. Agreed to the conference report on S. 21, the proposed Water Resources Planning Act (pp. 16142-4). This bill will now be sent to the President. See Digest 123 for provisions of this bill.

Sens. Anderson, McGee, and Javits expressed concern over the water shortage in many parts of the Nation and inserted an article, "Special Report: A Nation Can Dry Up." pp. 16127-9, 16130-2, 16134-7

3. SALINE WATER. Conferees were appointed on S. 24, to expand, extend, and accelerate the saline water conversion program conducted by Interior (p. 16144). House conferees have not yet been appointed.
4. ELECTRIFICATION. Sen. Thurmond criticized Secretary of the Interior Udall's "attempt to block Duke Power Co. from constructing a proposed \$700 million power generating complex" in S. C., and inserted several items in support of his criticism. pp. 16190-5
5. WATERSHEDS. The Public Works Committee approved plans for works of improvement on the following watersheds: Cooper Creek, Ark.; Lower Little Tallapoosa River, Ga. and Ala.; Limestone Stream, Me.; Long Creek, Miss.; Tuscumbia River, Miss. and Tenn.; Grindstone-Lost-Muddy Creek, Mo.; Stewarts Creek-Lovills Creek, N. C. and Va.; Uncle John Creek, Okla.; Upper Elk Creek, Okla.; Wilson Spring Creek, Tenn.; Attoyac Bayou, Tex.; Castleman Creek, Tex.; Donahoe Creek, Tex.; and Ferron, Utah. pp. 16124-5
6. BUILDINGS. Sen. McNamara submitted a listing of public building prospectuses approved by the Public Works Committee. pp. 16123-4

HOUSE

7. INSPECTION SERVICES. Rep. Cabell praised the "highly valuable but little publicized" quarantine service of USDA stating that it "has saved consumers and the economy untold millions of dollars." p. 16252
8. FARM PROGRAM. Rep. MacGregor inserted an article, "The Back of Freeman's Hand," critical of the Secretary's "ridicule" of those who have "questioned Department proposals." pp. 16260-1
Rep. Findley called the farm bill the "most expensive...in the history of farm legislation" and inserted a 4-year breakdown of the estimated costs. pp. 16261-2
Rep. Purcell spoke in favor of the farm bill and said, "Let us not be fooled by any fraudulent 'bread tax' arguments against it." p. 16281
9. PERSONNEL. The Rules Committee reported a resolution for the consideration of H. R. 8469, to provide certain increases in annuities payable from the civil service retirement and disability fund. p. 16206
10. HIGHWAYS. The Public Works Committee reported with amendment H. R. 6790, to increase the limitation on emergency relief for the repair or reconstruction of highways under 23 U.S.C. 125 (H. Rept. 614). p. 16286
11. ATOMIC ENERGY; ELECTRIFICATION. The Rules Committee reported a resolution for the consideration of H. R. 8856, to amend the Atomic Energy Act to clarify the intent of Congress regarding regulation of the sale, generation, or transmission of electric power produced through the use of nuclear facilities licensed by the Atomic Energy Commission. pp. 16251-2
12. EDUCATION. The Education and Labor Committee was granted until midnight July 14 to file a report on H. R. 9567, the proposed Higher Education Act. p. 16252

I invite the attention of the able Senator from California to the language in the House report which states:

No river basin commission established under this act will have authority to study the importation of water into the area over which it has jurisdiction from any other basin.

Madam President, I ask unanimous consent that a portion of page 12 of the report be printed at this point in the RECORD.

There being no objection, the excerpt was ordered to be printed in the RECORD, as follows:

INTERBASIN TRANSFERS OF WATER

The conference committee adopted language in the form of an additional disclaimer in section 3 which relates to studies of the transfer of waters between areas that are under the jurisdiction of more than one river basin commission or similar planning entity. The language states that nothing in the act shall be construed—

“(d) As authorizing any entity established or acting under the provisions hereof to study, plan, or recommend the transfer of waters between areas under the jurisdiction of more than one river basin commission or entity performing the function of a river basin commission.”

This language is intended to make it clear that the authority which is given to the Water Resources Council and to the river basin commissions established under S. 21 does not include authority to study and report upon the transfer of waters between basins or areas that are appropriate for planning on a comprehensive basis. In other words, no river basin commission established under this act will have authority to study the importation of water into the area over which it has jurisdiction from any other basin or related group of river basins under the jurisdiction of another river basin commission or entity performing the planning function of a river basin commission. Neither could a river basin commission study the exportation of water from the basin or area under its jurisdiction.

Likewise, the authority given the Council under this act does not include authority to study the transfer of waters between basins or areas covered by river basin commissions or similar planning entities.

Mr. KUCHEL. Madam President, I believe that is important because apparently all Members of Congress understand that the President himself has recommended that Congress give consideration to the water needs of the entire Nation through a suitable study, something of which I most sincerely and enthusiastically approve.

I look upon the people of the United States as one society in which some are blessed and others are not, in various categories of natural resources, including water. However, I am free to concede that that problem is not involved in this legislation, which restricts the entities created in its provisions to a certain kind of study, a study of each basin by those who are most interested in it, those who live there, with the cooperation of the Government of the United States.

The provisions of the bill will operate only on that which is created by its terms. Therefore, we should wait, as men of good will trying to organize and achieve a solution to the problems, by which solution all sections of the coun-

try may be benefited after a suitable study by a commission under the chairmanship, in this body, of my able friend the Senator from Washington [Mr. JACKSON].

Mr. JACKSON. Madam President, will the Senator yield?

Mr. KUCHEL. I yield.

Mr. JACKSON. Madam President, I believe that Senators, in examining the conference report, must keep in mind that this is a river basin planning proposal.

What we did in connection with the meeting of the conferees was to make clear that there would not be any misunderstanding of this point. It was limited to river basin studies on the basis of Federal, State, and local cooperation.

This is a new legal vehicle, created for the purpose of permitting Federal, State, and local entities to have an opportunity to work and plan together within each river basin.

This language was put in to make sure that the purpose would be confined exactly to what the original sponsors of the bill had said it would be.

I should say to my able and distinguished friend the Senator from California that I am deeply concerned about water problems all over the country.

The able Senator from New Mexico very properly referred to the announcement from the Associated Press tape which stated the President has asked the Water Resources Council to look into the acute situation that exists in the Delaware River Basin, affecting particularly the States of New Jersey and New York, in which water rationing is in effect for human consumption.

Madam President, at this time I ask unanimous consent to have printed at this point in the RECORD the item from the ticker tape to which the Senator from New Mexico referred.

There being no objection, the item was ordered to be printed in the RECORD, as follows:

WASHINGTON.—President Johnson asked administration agencies today for a report within a week on how resources of the Federal Government can be mobilized to help cope with the serious water shortage in the East.

The report will come from a water resources council of which Secretary of the Interior Stewart L. Udall is chairman. The President asked Udall to convene the council immediately, together with officials of Federal agencies concerned with water resources, “to assess what further actions might be taken to assist the States in meeting the problems now confronting the New England and Middle Atlantic region.”

The council, Johnson said in a statement, will obtain the views of the Delaware River Basin Commission. This is involved because New York draws water from the Delaware Basin and the river is so low now that salt water from lower reaches of the river is threatening the Philadelphia water supply.

The President announced his action after a conference with Buford Ellington of the Office of Emergency Planning.

Mr. JACKSON. Mr. President, I say to my able and distinguished friend from California that we, as members of the committee, feel that we have a national responsibility. We want to look at the water problems throughout the country

and see to it, within the jurisdiction of our committee, that we discharge our responsibilities. I assure the Senator that we are trying to do this.

As the Senator knows, because he has worked very closely with the Senator from New Mexico on the water desalination program, the State of California and other States of the southwest, including Arizona, New Mexico, and Nevada, face very real problems in this area.

We are attempting to study vigorously and fairly every possible means of expediting the water desalination program. It offers great promise, as the Senator knows, for obtaining not only water, but electric power. I believe the Bechtel report, sponsored jointly by the Metropolitan Water District, Department of Interior, and AEC, which was given considerable publicity recently, indicates that we shall be able to get the cost of water through that process down to as little as 21.4 cents per thousand gallons. This is one approach we have pushed vigorously in the committee.

I know of the Senator's deep concern and I appreciate, as do all the members of the committee, his desire for a continuous effort to try to find a solution that will be fair and equitable to all the States.

Mr. KUCHEL. I could not ask for any more freely stated or more constructive statement than the Senator has given, because the problem of water is a national problem.

What some of us, including the Senator from New Mexico, the Senator from Washington, and other Senators, undertook several years ago, pioneering in the legislative field for the development of potable water taken from the seas and from brackish water was a great piece of legislation. I was associated with that effort. I continue to put myself in that position.

My reason for rising on this occasion is to make it abundantly clear that such recommendations as the President has made to meet the national water needs would not be interfered with by the proposed legislation.

Mr. FANNIN. Madam President, since the State I represent is vitally concerned with the water problem also, and I am vitally concerned with what has been said in the past few days regarding the drought areas and the necessity for better water distribution in the various States that need it, I would like to pose some questions to the Senator from New Mexico.

The Secretary of the Interior has under study what is known as the North American water and power alliance and the Pacific Southwest water plan. Does the Senator feel that this bill interferes with those programs?

Mr. ANDERSON. I do not.

Mr. FANNIN. Does the Senator think this legislation will be helpful in these programs?

Mr. ANDERSON. I think whatever information we can get will help make possible the development of additional plans at the proper time.

Mr. FANNIN. Then the Senator is not concerned that this bill will impede the

studies now in progress and contemplated.

Mr. ANDERSON. No, indeed; not at all; because this act could well be, in the final analysis of help to every area that is short of water in the country.

The PRESIDING OFFICER. The question is on agreeing to the conference report.

The report was agreed to.

Mr. JACKSON. Madam President, I move to reconsider the vote by which the conference report was agreed to.

Mr. ANDERSON. Madam President, I move to lay that motion on the table.

The motion to lay on the table was agreed to.

EXPANSION OF SALINE WATER CONVERSION PROGRAM

Mr. ANDERSON. Madam President, I ask the Chair to lay before the Senate the amendment of the House of Representatives to S. 24.

The PRESIDING OFFICER laid before the Senate the amendment of the House of Representatives to the bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, which was, to strike out all after the enacting clause and insert:

That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951 et seq.), is hereby further amended as follows:

(1) In section 2(b) add the words "module, component," after the word "laboratory".

(2) In section 8 substitute the figure "\$85,000,000" for the figure "\$75,000,000".

Mr. ANDERSON. Madam President, I move that the Senate disagree to the amendment of the House and ask for a conference with the House on the disagreeing votes of the two Houses thereon, and that the Chair appoint conferees on the part of the Senate.

The motion was agreed to; and the Presiding Officer appointed Mr. JACKSON, Mr. ANDERSON, Mr. BIBLE, Mr. KUCHEL, and Mr. ALLOTT conferees on the part of the Senate.

DEATH OF HON. ADLAI E. STEVENSON

Mr. DOUGLAS. Madam President, the ticker tape has just conveyed the sad news of the sudden death of Hon. Adlai Stevenson. This is a great loss to the world and the Nation, as well as to our own State of Illinois.

Governor Stevenson was the Governor of the State of Illinois for 4 years, and made a distinguished record as chief executive.

He was twice the Democratic candidate for the presidency of the United States, and although he was unsuccessful in each instance, he raised the whole level of political discussion in this Nation and afforded an example to all politicians of the way in which a candidate should make an honorable campaign for high office.

In 1961, Adlai Stevenson was appointed as our official representative in

the United Nations, and for more than 4 years he represented the United States in that body.

In that capacity he always defended the legitimate interests of the United States. At the same time he sought for world peace and won the respect and affection of the people of the world.

His death is a great loss to all of us. It is a personal loss to me because when he ran for Governor I ran for the U.S. Senate, and we have always been political associates and personal friends.

We shall miss Governor Stevenson very much, but we are grateful for the example which he set, and the Nation is richer in both a spiritual and intellectual sense because of the fact that he lived.

Mr. JAVITS. Madam President, will the Senator from Illinois yield?

The PRESIDING OFFICER. Will the Senator from Illinois yield to the Senator from New York?

Mr. DOUGLAS. I yield.

Mr. JAVITS. I yield to the Senator from Colorado, who was a colleague of Governor Stevenson.

The PRESIDING OFFICER. The Senator from Colorado, is recognized.

Mr. ALLOTT. Madam President, I appreciate the distinguished Senator from New York yielding.

I wish to add a word to what the distinguished Senator from Illinois has said about the unfortunate death of Adlai Stevenson.

It is not an unusual thing that many of the political philosophies which he embraced and those which I embrace are pretty far apart, at opposite ends of the poles.

Nevertheless as a delegate to the United Nations in 1962, at the 17th General Assembly, appointed by President Kennedy, I had an opportunity to see the Ambassador in his work and in action. That period was during the Cuban crisis, in which times were extremely difficult.

In tribute to Adlai Stevenson, I have always regarded him since that time as a personal friend. He recognized the political ideological differences which separated us, and yet, in any conference of the American delegation, he always gave a full opportunity for me to express my views, and those views were not simply expressed and discarded. They were given full consideration along with the views of everyone else.

I feel that no matter how any one may have differed from him politically, he was a man who served his country well, and served his country to the maximum of his ability.

He was a brilliant man.

I feel a deep sense of loss in the tragic news that we have just received.

Mr. JAVITS. Madam President, I join my colleagues in this tribute to Adlai Stevenson. I am deeply shocked and grieved by his sudden passing. I knew him well. For many years he lived in New York City. I visited his home, and he visited ours. I often had contacts with him in connection with his work as U.S. Representative to the United Nations.

In a moment like this, everything is laid aside except the knowledge that his was one of the most eloquent voices that

freedom has ever known in all mankind's history.

As the distinguished senior Senator from Colorado [Mr. ALLOTT] has said, not only was Adlai Stevenson a brilliant man; his brilliance found a remarkably gracious, memorable, and even unique expression, not only in the United States, but throughout the world.

Perhaps the greatest tribute we can pay to so distinguished an American, who literally laid down his life for the cause of our country's advancement and for freedom in the world—because he really did nothing else but work in the last 10 years and, I know, for years before that, when I did not know him so well—is to say that he was in every sense of the word the representative of the United States at the United Nations, that great world hope for peace and rule by law instead of rule by force.

Every American can be proud that Adlai Stevenson epitomized in his person and in his advocacy what every American would expect of the voice of the United States in the United Nations in its expressiveness, in its idealism, in its practical content, and in the great influence which he had upon his colleagues and upon the representatives of other nations by the sheer force of his character, intellect, integrity, and ideas.

No American, regardless of party, need stint in any way in praise and tribute to Adlai Stevenson.

Mr. AIKEN. Madam President, I can add little to what has already been said concerning the untimely death of Adlai Stevenson. It has been my privilege to work with him for several years. He worked conscientiously and well. He was respected by the people of all countries, whether they agreed with his positions or not. It is most unfortunate that at a time like this, when he is perhaps needed more than ever, he should be called away.

Mr. KUCHEL. Madam President, the news is stunning, and the great and grievous loss to our country and to the cause of freedom is most profound and overwhelming.

The late Adlai Stevenson was superbly gifted for leadership in Government. Dedicated to the public service, he studied very long and very hard to find, as he saw the light, what best served the people. He demonstrated in his lifetime an elegant and telling facility of expression, at once eloquent and persuasive. Surely, as the voice of the people of the United States in the United Nations, the town meeting of the world, he gave vigor and stature to the positions of our Government, on all those varied and complex questions which concern the very future of the world. He stood up, stern and unyielding, to the merciless outpourings of Communist propaganda. I knew the late Adlai Stevenson solely by reputation, until during the administration of the late President Kennedy when I was appointed as a minority member of the delegation headed by the present Chief Executive, the then Vice President, and by the late Ambassador Stevenson together with Henry Labouisse, of the State Department, to pay the official respects of this

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HIGHLIGHTS: Sen. Harris criticized fees established under Land and Water Conservation Fund. Sen. Kuchel urged increased production of "quality" cotton to compete with synthetics. Rep. Ashbrook criticized alleged "partisan policies" to promote passage of farm bill. Rep. Purcell urged passage of farm bill.

SENATE

1. **FORESTRY.** The Interior and Insular Affairs Committee reported with amendments S. 1764, to authorize the acquisition of certain lands within the boundaries of the Uinta National Forest, Utah (S. Rept. 467). p. 16743
2. **VETERANS' BENEFITS.** By a vote of 69 to 17, passed as reported S. 9, to give cold war veterans educational and home-loan benefits similar to those of World War II and Korean conflict veterans, including institutional on-farm training and home and farm loan assistance by the Veterans Administration. pp. 16672-4, 16676-7, 16679-82, 16684-724

3. LANDS. The Interior and Insular Affairs Committee voted to report (but did not actually report) S. 625, with amendment, to authorize the sale of certain or disconnected tracts of land, and S. 1190, to provide that certain limitations shall not apply to certain land patented to Alaska for the use of the University of Alaska. p. D665
 4. RECLAMATION. The Interior and Insular Affairs Committee voted to report (but did not actually report) S. 34, with amendment, to make certain provisions in connection with construction of the Garrison diversion unit, Missouri River Basin project. p. D665
 5. RESEARCH. Passed as reported S. 949, to authorize a 5-year program of matching grants to the States by the Commerce Department in a cooperative effort to promote the wider diffusion and more effective application of the findings of science and technology throughout commerce and industry. pp. 16728-32
 6. HEALTH. Conferees were appointed on S. 510, to extend and amend certain expiring provisions of the Public Health Service Act relating to community health services (p. 16672). House conferees have already been appointed.
 7. USER CHARGES; CONSERVATION. Sen. Harris criticized user charges established under the Land and Water Conservation Fund, urged enactment of legislation to give Congress veto power over any fees established by Federal agencies, and inserted an Okla. Legislature resolution in support of his position. p. 16645
 8. COTTON. Sen. Kuchel urged increased production of "quality" cotton to compete more effectively with synthetics, expressed opposition to payment of price supports "on cotton that is not of sufficiently high quality to be used in our high-speed and efficient modern textile mills," and inserted a letter from the president of the Western Cotton Growers Assoc. in support of his position. p. 16657
 9. HOUSING LOANS. Conferees were appointed by both Houses on H. R. 7984, the housing and urban development bill. pp. 16555, 16700
Sen. Byrd, W. Va., inserted an article by Vice President Humphrey reviewing and commending the housing and urban development bill. pp. 16660-1
 10. PUBLIC WORKS; FLOOD CONTROL. The Public Works Committee reported an original bill, S. 2300, to authorize the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and other purposes (S. Rept. 464). p. 16646
 11. DISASTER RELIEF. Passed over, at the request of Sen. Inouye, S. 1861, to provide additional assistance for areas suffering a major disaster. p. 16644
- HOUSE
12. LEGISLATIVE BRANCH APPROPRIATION BILL, 1966. Conferees were appointed on this bill, H. R. 8775, which includes items for the Government Printing Office and the Library of Congress (pp. 16553-5). Senate conferees have already been appointed.
 13. SALINE-WATER; RESEARCH. Conferees were appointed on S. 24, to expand, extend, and accelerate the saline water conversion program conducted by Interior (p. 16555). Senate conferees have already been appointed.

There are one or two others. They are all set out in the bill and explained in the committee report.

Mr. REIFEL. Mr. Speaker, will the gentleman yield for an observation?

Mr. GEORGE W. ANDREWS. I yield to the gentleman.

Mr. REIFEL. Under the rule of comity, the other body may decide what its expenditures will be and propose them in this bill, and we are also permitted to do the same thing here in the House. Is that correct?

Mr. GEORGE W. ANDREWS. That has been the practice in these annual legislative appropriation bills, I might say to the gentleman.

Mr. REIFEL. Mr. Speaker, I withdraw my reservation.

The SPEAKER. Is there objection to the request of the gentleman from Alabama?

Mr. GROSS. Mr. Speaker, further reserving the right to object, there is one significant difference in the procedure of handling the so-called housekeeping bill on the part of the other body and the House. The House lays before the other body its requests and asks them to approve, but we seldom on this side have an opportunity to know what the other body is doing. Yet we are called upon to put our stamp of approval upon what they do. Insofar as the House is concerned and what we do, they have this laid out before them.

While I appreciate the fact that the gentleman from Alabama has given us some insight into what the other body is doing, I still hope that somehow or other, at some distant day in the future, we may have the opportunity really to go into what the other body presents to us and which they ask us to approve.

Insofar as the rule of comity is concerned, I have looked long and hard in the rule book to find the rule of comity, and I do not believe it exists, certainly not under that title.

Mr. GEORGE W. ANDREWS. Mr. Speaker, I thank the gentleman.

Mr. GROSS. Mr. Speaker, I withdraw my reservation.

The SPEAKER. Is there objection to the request of the gentleman from Alabama?

There was no objection.

The Senate amendments referred to were concurred in.

A motion to reconsider was laid on the table.

Mr. GEORGE W. ANDREWS. Mr. Speaker, I ask unanimous consent that the House disagree to the remainder of the amendments of the Senate to the bill H.R. 8775 and agree to the conference asked by the Senate.

The SPEAKER. Is there objection to the request of the gentleman from Alabama? The Chair hears none and appoints the following conferees: Messrs. GEORGE W. ANDREWS, STEED, KIRWAN, SLACK, FLYNN, MAHON, LANGEN, REIFEL, and JONAS.

PERMISSION TO FILE CONFERENCE REPORT ON H.R. 8775

Mr. GEORGE W. ANDREWS. Mr. Speaker, I ask unanimous consent that

the managers on the part of the House on the conference on the disagreeing votes of the two Houses on the bill (H.R. 8775) making appropriations for the legislative branch for the fiscal year ending June 30, 1966, and for other purposes, may have until midnight tomorrow night to file a conference report.

The SPEAKER. Is there objection to the request of the gentleman from Alabama?

There was no objection.

SALINE WATER CONSERVATION PROGRAM

Mr. ASPINALL. Mr. Speaker, I ask unanimous consent to take from the Speaker's table the bill S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, with a House amendment thereto, insist on the House amendment, and agree to the conference asked by the Senate.

The SPEAKER. Is there objection to the request of the gentleman from Colorado? The Chair hears none, and appoints the following conferees: Messrs. ASPINALL, O'BRIEN, ROGERS of Texas, SAYLOR, and REINECKE.

HOUSING AND URBAN DEVELOPMENT ACT OF 1965

Mr. PATMAN. Mr. Speaker, I ask unanimous consent to take from the Speaker's table the bill H.R. 7984, to assist in the provision of housing for low- and moderate-income families, to promote orderly urban development, to improve living environment in urban areas, and to extend and amend laws relating to housing, urban renewal, and community facilities, with Senate amendments thereto, disagree to the Senate amendments, and request a conference with the Senate.

The SPEAKER. Is there objection to the request of the gentleman from Texas?

The Chair hears none and appoints the following conferees: Messrs. PATMAN, MULTER, BARRETT, Mrs. SULLIVAN, and Messrs. REUSS, ASHLEY, WIDNALL, FINO, and Mrs. DWYER.

SUBCOMMITTEE NO. 4 OF SMALL BUSINESS COMMITTEE

Mr. EVINS of Tennessee. Mr. Speaker, I ask unanimous consent that Subcommittee No. 4 of the Small Business Committee have permission to sit during general debate this afternoon.

The SPEAKER. Is there objection to the request of the gentleman from Tennessee?

There is no objection.

SUBCOMMITTEE NO. 1 OF COMMITTEE ON THE JUDICIARY

Mr. ALBERT. Mr. Speaker, I ask unanimous consent that Subcommittee No. 1 of the Committee on the Judiciary have permission to sit during general debate today.

The SPEAKER. Is there objection to the request of the gentleman from Oklahoma?

Mr. HALL. Mr. Speaker, reserving the right to object, is that the Committee on Immigration?

Mr. ALBERT. The gentleman is correct.

Mr. HALL. Mr. Speaker, I object.

CONSENT CALENDAR

The SPEAKER. This is Consent Calendar Day. The Clerk will call the first bill on the Consent Calendar.

AMENDING TITLES 10 AND 14, UNITED STATES CODE, AND THE MILITARY PERSONNEL AND CIVILIAN EMPLOYEES' CLAIMS ACT OF 1964, WITH RESPECT TO THE SETTLEMENT OF CLAIMS AGAINST THE UNITED STATES BY MEMBERS OF THE UNIFORMED SERVICES AND CIVILIAN OFFICERS AND EMPLOYEES OF THE UNITED STATES FOR DAMAGE TO, OR LOSS OF, PERSONAL PROPERTY INCIDENT TO THEIR SERVICE, AND FOR OTHER PURPOSES

The Clerk called the bill (H.R. 5024) to amend titles 10 and 14, United States Code, and the Military Personnel and Civilian Employees' Claims Act of 1964, with respect to the settlement of claims against the United States by members of the uniformed services and civilian officers and employees of the United States for damage to, or loss of, personal property incident to their service, and for other purposes.

Mr. GROSS. Mr. Speaker, I ask unanimous consent that the bill be passed over without prejudice.

The SPEAKER. Is there objection to the request of the gentleman from Iowa?

There was no objection.

PROVIDING THAT THE SECRETARY OF THE INTERIOR SHALL CONVEY CERTAIN REAL PROPERTY TO THE COMMONWEALTH OF PUERTO RICO

The Clerk called the bill (H.R. 3433) to provide that the Secretary of the Interior shall convey certain real property to the Commonwealth of Puerto Rico.

Mr. HALL. Mr. Speaker, in view of the colloquy last week, I ask unanimous consent that the bill be passed over without prejudice.

The SPEAKER. Is there objection to the request of the gentleman from Missouri?

There was no objection.

AUTHORIZING LANGUAGE TRAINING FOR MEMBERS OF THE ARMED FORCES

The Clerk called the bill (H.R. 5519) to amend title 10, United States Code, to authorize language training to be given to a dependent of a member of the Army, Navy, Air Force, or Marine Corps under certain circumstances.

There being no objection, the Clerk read the bill, as follows:

H.R. 5519

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That chapter 101 of title 10, United States Code, is amended as follows:

(1) By adding the following new section:

"§ 2002. Dependents of members of Army, Navy, Air Force, or Marine Corps: language training

"(a) Notwithstanding section 1041 of title 22 or any other provision of law, and under regulations to be prescribed by the Secretary of Defense, language training may be provided in—

"(1) a facility of the Department of Defense;

"(2) a facility of the Foreign Service Institute established under section 1041 of title 22; or

"(3) a civilian educational institution; to a dependent of a member of the Army, Navy, Air Force, or Marine Corps in anticipation of the member's assignment to permanent duty outside the United States or while the dependent is accompanying the member outside the United States as a result of the member's assignment to that duty.

"(b) For the purposes of this section, the word 'dependent' has the same meaning that it has under section 401 of title 37".

(2) By inserting the following item in the analysis:

"2002. Dependents of members of Army, Navy, Air Force, or Marine Corps: language training."

The bill was ordered to be engrossed and read a third time, was read the third time, and passed, and a motion to reconsider was laid on the table.

Mr. PHILBIN. Mr. Speaker, this bill authorizes language training to the dependents of members of the Army, Navy, Air Force, and Marine Corps in anticipation of their sponsors' assignment to permanent duty outside the United States, or while they are accompanying members outside the United States as a result of the members' assignment to such duty.

NEED FOR LEGISLATION

Dependents of members of our military forces perform an important role in projecting a true image of the United States abroad. Their ability to speak the language of the country increases the effectiveness of their military sponsors and generates inestimable good will for the United States.

Congress recognized the contributions wives can make when it amended section 701 of the Foreign Service Act of 1946 (22 U.S.C. 1041) to permit the Secretary of State to provide appropriate orientation and language training to members of the families of officers and employees of the Government in anticipation of their sponsors' assignment abroad or while abroad.

Although section 701 of the Foreign Service Act of 1946 specifically established the Foreign Service Institute and as amended authorizes language training for dependents of military personnel, it limits such training to that which is accomplished at the Foreign Service Institute of the Department of State. The facilities of the Foreign Service Institute, in the United States, are located only in Washington, D.C. On the other hand, facilities of the Department of Defense are located in various places in the

United States including the Defense Language Institute West Coast Branch at Monterey, Calif., and at other Department of Defense education centers. These facilities provide language training to members of the Army, Navy, Air Force, and Marine Corps in anticipation of their assignment to duty outside the United States. So far as the Department of Defense is concerned, the requirement that dependents may be provided training only at the Foreign Service Institute would cause greater transportation costs than those resulting from having a number of locations, including the Foreign Service Institute, to which members and their dependents may go for training.

In those instances in which it may not be possible to provide language training to dependents in the United States, but in which such training is desirable, the proposed legislation would authorize the training to be given outside of the United States.

COST

In providing foreign language training under the proposed legislation, priority will be accorded to the wives of attaches, military assistance advisory group and mission personnel, and the personnel of international headquarters. It is estimated that the average annual input into this program will be 750 trainees. The first year cost of operation will be approximately \$200,000, and it is considered that the annual recurring cost will not exceed this amount.

DEPARTMENTAL POSITION

The Department of Defense recommends enactment of this legislation.

COMMITTEE POSITION

The House Armed Services Committee unanimously approved this legislation.

I am pleased that the House has enacted this measure.

SALE OF UNIFORM CLOTHING TO THE NAVAL SEA CADET CORPS AND STATE AND FEDERAL MARITIME ACADEMIES

The Clerk called the bill (S. 1856) to authorize the Secretary of the Navy to sell uniform clothing to the Naval Sea Cadet Corps.

There being no objection, the Clerk read the bill, as follows:

S. 1856

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That chapter 647 of title 10, United States Code, is amended—

(1) by inserting the following new section after section 7541:

"§ 7541a. Uniform clothing: sale to Naval Sea Cadet Corps

"Subject to regulations under section 486 of title 40, the Secretary of the Navy, under regulations prescribed by him, may sell any item of enlisted naval uniform clothing that may be spared, at a price representing its fair value, to the Naval Sea Cadet Corps for the sea cadets. The cost of transportation and delivery of items sold under this section shall be charged to the Naval Sea Cadet Corps."; and

(2) by inserting the following new item in the analysis:

"7541a. Uniform clothing: sale to Naval Sea Cadet Corps."

With the following committee amendments:

Page 2, line 1, insert after the word "cadets" the following words: "and to any Federal or State maritime academy having a department of naval science for the maritime cadets and midshipmen".

Page 2, line 3, insert after the word "Corps" the following words: "and to such Federal and State maritime academies".

The amendments were agreed to.

The bill was ordered to be read a third time, was read the third time, and passed, and a motion to reconsider was laid on the table.

CITY OF CLINTON BRIDGE COMMISSION

The Clerk called the bill (H.R. 3788) to revive and reenact as amended the act entitled "An act creating the City of Clinton Bridge Commission and authorizing said commission and its successors to acquire by purchase or condemnation and to construct, maintain, and operate a bridge or bridges across the Mississippi River at or near Clinton, Iowa, and at or near Fulton, Ill.," approved December 21, 1944.

The SPEAKER. Is there objection to the present consideration of the bill?

Mr. HALL. Mr. Speaker, reserving the right to object, I should like to inquire if this is the customary commission agreed to on any navigable stream between the two States involved?

Mr. BLATNIK. Mr. Speaker, will the gentleman yield?

Mr. HALL. I yield to the gentleman from Minnesota.

Mr. BLATNIK. The gentleman from Missouri asks if this is customary?

Mr. HALL. Is this the regular and established precedent for such commissions, which must be established?

Mr. BLATNIK. In this instance it is. This bill is identical with the bill passed by this body last year. This is necessary. The original authorization was back in 1944, and a subsequent bill was passed in 1946, the General Bridge Act of 1946.

Mr. HALL. This will merely continue the same Commission?

Mr. BLATNIK. That is correct.

Mr. HALL. It is without any authorization or appropriation or expense to the Government, but merely authorizes this and establishes the Commission therefor?

Mr. BLATNIK. That is correct. It extends the life of the Commission.

Mr. GROSS. Mr. Speaker, will the gentleman yield?

Mr. HALL. I am glad to yield to the gentleman from Iowa.

Mr. GROSS. This likely will be a toll bridge, is that not correct?

Mr. BLATNIK. That is correct.

Mr. HALL. Mr. Speaker, I withdraw my reservation.

The SPEAKER. Is there objection to the present consideration of the bill?

There being no objection, the Clerk read the bill as follows:

Be it enacted by the Senate and House of Representatives of the United States of

DIGEST of Congressional Proceedings

OF INTEREST TO THE DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C. 20250
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89th-1st; No. 137

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HIGHLIGHTS: Both Houses passed appropriations continuing resolution. Sen. Mondale expressed concern over "plight" of family farmer. Rep. Findley criticized cotton program. Rep. Fascell praised USDA consumer research program. Rep. Cooley submitted measure to provide for consideration of farm bill.

HOUSE

1. **ATOMIC ENERGY; ELECTRIFICATION.** Agreed to a Rules Committee resolution for the consideration of H. R. 8856, to amend the Atomic Energy Act to clarify the intent of Congress regarding regulation of the sale, generation, or transmission of electric power produced through the use of nuclear facilities licensed by the Atomic Energy Commission. pp. 17952-4

2. EDUCATION. Agreed to a Rules Committee resolution for the consideration of H. R. 8310, the proposed Educational Rehabilitation Act Amendments of 1965. p. 17954
3. PERSONNEL. The "Daily Digest" states that the Government Operations Committee voted to report (but did not actually report) H. R. 4653 (amended), to authorize checks to be drawn in favor of banking organizations for the credit of a person's account, under certain conditions; and H. R. 9020 (amended), to amend section 7 of the Administrative Expenses Act of 1946, as amended, to provide for the payment of travel costs for applicants invited by a department to visit it for purposes connected with employment. p. D713

The "Daily Digest" states that a subcommittee of the Post Office and Civil Service Committee "approved a subcommittee draft on the proposed Federal and postal pay raise." p. D714

4. FUND ADJUSTMENTS. "The "Daily Digest" states that the Government Operations Committee voted to report (but did not actually report) H. R. 6438 (amended), to authorize any executive department or independent establishment of the Government, or any bureau or office thereof to make appropriate reimbursement between the respective appropriations available to such departments and establishments, or any bureau or office thereof. p. D713
5. MILITARY CONSTRUCTION. The "Daily Digest" states that conferees agreed to file a report on H. R. 8439, fiscal 1966 authorizations for military construction, which includes a provision for reimbursement of CCC. p. D714

6. SALINE WATER RESEARCH. The "Daily Digest" states that conferees agreed to file a report on S. 24, to increase authorizations for expansion and extension of the saline water conversion program. p. D714

7. COTTON. Rep. Findley criticized the cotton proposal recently reported by the Agriculture Committee and the current cotton program, and inserted a USDA report on the first 11 months of its operation which he states shows that "mill margins are up again and so are textile prices." pp. 17974-5

8. CONSUMER RESEARCH. Rep. Fawell commended the USDA consumer research program for the numerous achievements in the revolution in food. p. 17983

9. WHEAT; FLOUR. Received from the State Dept. a reply to the GAO report on "unnecessary costs resulting from an inflexible policy of donating flour instead of wheat to voluntary relief agencies for distribution abroad under the Agricultural Act of 1949." p. 17989

10. TRADE EXPANSION. Rep. Gross urged early consideration of proposed legislation to amend the Trade Expansion Act of 1962. pp. 17961-3

11. LEGISLATIVE PROGRAM. The "Daily Digest" states that today (Thurs.) the House will consider H. R. 8856, an amendment to section 271 of the Atomic Energy Act; and H. R. 8310, to amend the Vocational Rehabilitation Act. p. D713

SENATE

12. APPROPRIATIONS. Both Houses passed without amendment H. J. Res. 591, the appropriations continuing resolution (pp. 17804-5, 17806, 17885-7). This

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Issued August 4, 1965
For actions of August 3, 1965
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HIGHLIGHTS: House subcommittee approved bill to expand various FHA loan authorities. Rep. Adams commended USDA meat and poultry inspection service. Rep. Purcell commended USDA services for consumers. Rep. Hathaway defended price of potatoes. Senate committees reported Labor-HEW appropriation bill and proposed Intergovernmental Cooperation Act (grants-in-aid, etc.) Rep. Ryan introduced and discussed bill to establish Federal Water Commission.

SENATE

1. INTERGOVERNMENTAL RELATIONS. The Government Operations Committee reported with amendments S. 561, the proposed Intergovernmental Cooperation Act of 1965 (grants-in-aid, etc.) (S. Rept. 538). p. 18355
2. LABOR-HEW APPROPRIATION BILL, 1966. The Appropriations Committee reported with amendments this bill, H. R. 7765. (S. Rept. 537). p. 18355

3. PERSONNEL; PAYROLLING. Passed with amendments S. 1309, to authorize checks to be drawn in favor of financial organizations for the credit of a person's account, under certain conditions. p. 18460
4. BALANCE OF PAYMENTS. Sen. Symington discussed the "continuing unfavorable balance of payments" situation. pp. 18372-4
5. HUNGER EXPLOSION. Sen. Mondale spoke on the "danger of the world's hunger explosion" and inserted two editorials, "The Poor Are Engulfing the Earth," and "U. S. Acts To Raise World Nutrition." pp. 18378-81
6. OCEANOGRAPHY. Sen. Murphy spoke in support of the bill to provide for expanded research in the oceans and the Great Lakes and to establish a National Oceanographic Council, and paid tribute to San Diego for "its world leadership" in this field. p. 18383
7. FALLOUT. Sen. Bartlett stated "the contamination of the Arctic Alaska food chain by radioactive fallout increases day by day" and urged that we step up our research on radiation and radiation surveillance and countermeasures. pp. 18471-5

HOUSE

8. LOANS. The Subcommittee on Conservation and Credit of the Agriculture Committee "approved for full committee action a subcommittee print (a clean bill to be introduced" to authorize grants and insured loans by the Farmers Home Administration for small community water systems and to increase the authorization for its insured real estate loans. p. D739
9. SALINE WATER. Received the conference report on S. 24, to expand, extend, and accelerate the saline water conversion program of the Department of the Interior (H. Rept. 720). pp. 18499-500
10. MILITARY CONSTRUCTION. Received the conference report on H. R. 8439, the military construction bill, which includes an item for payment of CCC for certain family housing which was financed from the sale of surplus commodities (H. Rept. 713). pp. 18476-89
11. VOTING RIGHTS; PERSONNEL. Agreed to, 328 to 74, the conference report on S. 1564, the voting rights bill, which includes authorization for the Civil Service Commission to appoint examiners, including Federal employees, to consider cases in which it is alleged that persons have been denied the right to vote on account of race or color. pp. 18476, 18489-99
12. APPROPRIATIONS. The Government Operations Committee reported with amendment H. R. 6438, to authorize any Federal Department, or any bureau or office thereof, to make appropriate reimbursement between the respective appropriations available to such departments, or any bureau or office thereof (H. Rept. 722). p. 18593
13. EMPLOYMENT. The Education and Labor Committee reported without amendment H. R. 10065, to more effectively prohibit discrimination in employment because of race, color, religion, sex, or national origin (H. Rept. 718). p. 18593

SALINE WATER CONVERSION PROGRAM

AUGUST 3, 1965.—Ordered to be printed

Mr. ASPINALL, from the committee of conference, submitted the following

CONFERENCE REPORT

[To accompany S. 24]

The committee of conference on the disagreeing votes of the two Houses on the amendment of the House to the bill (S. 24) entitled "An Act to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes", having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the Senate recede from its disagreement to the amendment of the House and agree to the same with an amendment as follows:

In lieu of the language inserted by paragraph (2) of the House amendment, insert the following:

(2) *In section 8 substitute "\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000," in lieu of "\$75,000,000 in all," and substitute "1972" for "1967".*

And the House agree to the same.

WAYNE N. ASPINALL,
LEO W. O'BRIEN,
WALTER ROGERS,
JOHN P. SAYLOR,
ED REINECKE,

Managers on the Part of the House.

HENRY M. JACKSON,
CLINTON P. ANDERSON,
ALAN BIBLE,
THOMAS H. KUCHEL,
GORDON ALLOTT,

Managers on the Part of the Senate.

STATEMENT OF MANAGERS ON THE PART OF THE HOUSE

The managers on the part of the House at the conference on the disagreeing votes of the two Houses on the amendment of the House to the bill, S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, submit this statement in explanation of the effect of the language agreed upon and recommended in the accompanying conference report.

Paragraph (2) of the Senate-passed bill reads as follows:

(2) In section 8 substitute the figure "\$275,000,000" for the figure "\$75,000,000" and the figure "1972" for the figure "1967".

Paragraph (2) of the House amendment reads as follows:

(2) In section 8 substitute the figure "\$85,000,000" for the figure "\$75,000,000".

The conference committee adopted language in lieu of paragraph (2) of the House amendment reading as follows:

(2) In section 8 substitute "\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000," in lieu of "\$75,000,000 in all," and substitute "1972" for "1967".

With the incorporation in the basic act of this language adopted by the conference committee, section 8 will read as follows:

SEC. 8. There are authorized to be appropriated such sums, to remain available until expended, as may be necessary, but not more than \$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000, (a) to carry out the provisions of this Act during the fiscal years 1962 to 1972, inclusive; (b) to finance, for not more than two years beyond the end of said period, such grants, contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act; and (c) to finance, for not more than three years beyond the end of said period, such activities as are required to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act: *Provided*, That funds available in any one year for research and development may, subject to the approval of the Secretary of State to assure that such activities are consistent with the foreign policy objectives of the United States, be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That every such contract or agreement made with any public or private agency in a foreign country shall contain provisions effective to insure that the results or information developed in con-

nection therewith shall be available without cost to the United States for the use of the United States throughout the world and for the use of the general public within the United States.

Paragraph (2) of the Senate-passed bill would have extended the program for an additional 5 years through fiscal year 1972 and authorized an additional \$200 million to be appropriated for carrying out the research and development work, making available \$220 million for the 6-year period fiscal year 1967-72, inclusive. Paragraph (2) of the House amendment would have authorized only an additional \$10 million to be appropriated for fiscal year 1967, making available a total of \$30 million for research and development work in fiscal year 1967.

The effect of the language adopted by the conference committee is (1) to extend the saline water research and development program for an additional 5 years through fiscal year 1972; (2) to authorize an additional \$15 million to be appropriated for research and development work, which amount, when added to previously authorized but unappropriated funds, makes available \$35 million for appropriation after fiscal year 1966; and (3) to require additional authorization by the Congress for the appropriation of amounts above \$90 million, with such additional amounts limited to \$185 million.

The language recommended by the conference committee is necessary, in our judgment, if the responsibilities of the Congress for this program are to be met. The adoption of this language is not to be interpreted as a lack of confidence in the executive branch. The inclusion of the \$185 million figure indicates approval for planning purposes of the full program recommended by the President.

By its very nature, saline water conversion is a program where it is quite uncertain from one year to the next what direction the research effort is to take. It is understandable that the program presented to the Congress for the 5-year extension was in terms only of the goals which it was hoped might be attained. The prosecution of this program for another 5 years will involve important policy decisions which cannot be made at this time—decisions which are primarily the responsibility of the Congress.

Under the language adopted by the conference committee, the program for the 5-year period can be planned and formulated as recommended by the President. The \$90 million ceiling on the amount authorized to be appropriated makes available \$35 million or \$6 million more than the preliminary program of the Office of Saline Water for fiscal year 1967. Beginning in fiscal year 1968, it is the position of the conference committee that the research and development work to be accomplished under this program should be approved on a year-by-year basis. Therefore, the Department of the Interior should submit to the Congress at the appropriate time legislation to approve the research and development work proposed to be accomplished in fiscal year 1968.

WAYNE N. ASPINALL,
LEO W. O'BRIEN,
WALTER ROGERS,
JOHN P. SAYLOR,
ED REINECKE,

Managers on the Part of the House.

Minshall	Redlin	Stafford
Mize	Reid, Ill.	Staggers
Moeller	Reid, N.Y.	Stalbaum
Monagan	Reifel	Stanton
Moore	Reinecke	Steed
Moorhead	Resnick	Stratton
Morgan	Reuss	Stubblefield
Morris	Rhodes, Ariz.	Sullivan
Morrison	Rhodes, Pa.	Sweeney
Morse	Robison	Talcott
Mosher	Rodino	Teague, Calif.
Moss	Rogers, Colo.	Tenzer
Multer	Rogers, Fla.	Thompson, N.J.
Murphy, Ill.	Rohan	Thompson, Tex.
Murphy, N.Y.	Rooney, N.Y.	Thomson, Wis.
Natcher	Rooney, Pa.	Todd
Nedzi	Roosevelt	Trimble
Nix	Rosenthal	Tunney
O'Brien	Rostenkowski	Tupper
O'Hara, Ill.	Roudebush	Udall
O'Hara, Mich.	Roush	Ullman
O'Konski	Roybal	Van Deerlin
Olsen, Mont.	Rumsfeld	Vanik
Olson, Minn.	Ryan	Vigorito
O'Neill, Mass.	St Germain	Vivian
Ottinger	St. Onge	Walker, N. Mex.
Patman	Saylor	Watkins
Patten	Schisler	Weltner
Pelly	Schmidhauser	Whalley
Pepper	Schneebell	White, Idaho
Perkins	Schweiker	White, Tex.
Philbin	Secret	Widnall
Pickle	Senner	Wilson, Bob
Pike	Shipley	Wilson,
Pirnie	Shriver	Charles H.
Price	Sickles	Wolff
Pucinski	Sisk	Wyatt
Purcell	Skubitz	Wylder
Quile	Slack	Yates
Quillen	Smith, Iowa	Young
Race	Smith, N.Y.	Younger
Randall	Springer	Zablocki

NAYS—74

Abbitt	Fountain	O'Neal, Ga.
Abernethy	Fuqua	Passman
Andrews,	Gathings	Poage
George W.	Gettys	Poff
Andrews,	Gross	Pool
Glenn	Gurney	Rivers, S.C.
Beckworth	Hagan, Ga.	Roberts
Broyhill, N.C.	Haley	Rogers, Tex.
Broyhill, Va.	Hansen, Idaho	Satterfield
Buchanan	Hardy	Scott
Burleson	Harris	Selden
Callaway	Hébert	Sikes
Casey	Henderson	Smith, Calif.
Cooley	Jonas	Smith, Va.
Davis, Ga.	Jones, Ala.	Stephens
Davis, Wis.	Kornegay	Teague, Tex.
Dickinson	Landrum	Tuck
Dorn	Lennon	Tuten
Dowdy	Long, La.	Utt
Downing	McEwen	Waggonner
Edwards, Ala.	Marsh	Watson
Everett	Martin, Ala.	Whitener
Fino	Matthews	Whitten
Fisher	Michel	Willis
Flynt	Mills	
	Murray	

NOT VOTING—32

Ashley	Hosmer	Roncallo
Baring	Jones, Mo.	Scheuer
Battin	Keogh	Taylor
Bingham	Laird	Thomas
Bonner	Lindsay	Toll
Cahill	McMillan	Walker, Miss.
Carey	Martin, Mass.	Watts
Colmer	Morton	Williams
Green, Oreg.	Nelsen	Wright
Hall	Powell	
Holfield	Rivers, Alaska	

So the conference report was agreed to.

The Clerk announced the following pairs:

On this vote:

Mr. Keogh for, with Mr. Colmer against.
Mr. Holfield for, with Mr. Bonner against.
Mrs. Green of Oregon for, with Mr. Taylor against.

Mr. Roncallo for, with Mr. Williams against.

Mr. Rivers of Alaska for, with Mr. McMillan against.

Mr. Martin of Massachusetts for, with Mr. Walker of Mississippi against.

Mr. Hosmer for, with Mr. Battin against

Until further notice:

Mr. Thomas with Mr. Laird.
Mr. Carey with Mr. Lindsay.
Mr. Ashley with Mr. Hall.
Mr. Bingham with Mr. Nelsen.
Mr. Toll with Mr. Morton.
Mr. Wright with Mr. Watts.
Mr. Powell with Mr. Scheuer.

The result of the vote was announced as above recorded.

A motion to reconsider was laid on the table.

GENERAL LEAVE TO EXTEND

Mr. CELLER. Mr. Speaker, I ask unanimous consent that all Members may have 5 legislative days in which to extend their remarks on the conference report just agreed to.

The SPEAKER. Without objection, it is so ordered.

There was no objection.

AMENDING PEACE CORPS ACT

Mr. MORGAN. Mr. Speaker, I ask unanimous consent to take from the Speaker's table the bill (S. 2054) to amend further the Peace Corps Act (75 Stat. 612), as amended, and for other purposes, with House amendments thereto, insist on the House amendments and agree to the conference requested by the Senate.

The SPEAKER. Is there objection to the request of the gentleman from Pennsylvania? [After a pause.] The Chair hears none and appoints the following conferees: Mr. MORGAN, Mr. ZABLOCKI, Mrs. KELLY, Mr. HAYS, Mrs. BOLTON, Mr. ADAMS, and Mr. MAILLIARD.

SALINE WATER CONVERSION PROGRAM

Mr. ASPINALL submitted the following conference report and statement on the bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, which was ordered to be printed:

CONFERENCE REPORT (H. REPT. No. 720)

The committee of conference on the disagreeing votes of the two Houses on the amendment of the House to the bill (S. 24) entitled "An Act to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes," having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the Senate recede from its disagreement to the amendment of the House and agree to the same with an amendment as follows: In lieu of the language inserted by paragraph (2) of the House amendment, insert the following:

"(2) In section 8 substitute '\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate, but not to exceed \$185,000,000,' in lieu of

'\$75,000,000 in all,' and substitute '1972' for '1967'."

And the House agree to the same.

WAYNE N. ASPINALL,
LEO W. O'BRIEN,
WALTER ROGERS,
JOHN P. SAYLOR,
ED REINECKE,

Managers on the Part of the House.

HENRY M. JACKSON,
CLINTON P. ANDERSON,
ALAN BIBLE,
THOMAS H. KUCHEL,
GORDON ALLOTT,

Managers on the Part of the Senate.

STATEMENT

The managers on the part of the House at the conference on the disagreeing votes of the two Houses on the amendment of the House to the bill, S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, submit this statement in explanation of the effect of the language agreed upon and recommended in the accompanying conference report.

Paragraph (2) of the Senate-passed bill reads as follows:

"(2) In section 8 substitute the figure '\$275,000,000' for the figure '\$75,000,000' and the figure '1972' for the figure '1967'."

Paragraph (2) of the House amendment reads as follows:

"(2) In section 8 substitute the figure '\$85,000,000' for the figure '\$75,000,000'."

The conference committee adopted language in lieu of paragraph (2) of the House amendment reading as follows:

"(2) In section 8 substitute '\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000,' in lieu of '\$75,000,000 in all,' and substitute '1972' for '1967'."

With the incorporation in the basic act of this language adopted by the conference committee, section 8 will read as follows:

"SEC. 8. There are authorized to be appropriated such sums, to remain available until expended, as may be necessary, but not more than \$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000, (a) to carry out the provisions of this Act during the fiscal years 1962 to 1972, inclusive; (b) to finance, for not more than two years beyond the end of said period, such grants, contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act; and (c) to finance, for not more than three years beyond the end of said period, such activities as are required to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act: *Provided*, That funds available in any one year for research and development may, subject to the approval of the Secretary of State to assure that such activities are consistent with the foreign policy objectives of the United States, be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That every such contract or agreement made with any public or private agency in a foreign country shall contain provisions effective to insure that the results or information developed in connection therewith shall be available without cost to the United States for the use of the United States throughout the world and for the use of the general public within the United States."

Paragraph (2) of the Senate-passed bill would have extended the program for an

additional 5 years through fiscal year 1972 and authorized an additional \$200 million to be appropriated for carrying out the research and development work, making available \$220 million for the 6-year period fiscal year 1967-72, inclusive. Paragraph (2) of the House amendment would have authorized only an additional \$10 million to be appropriated for fiscal year 1967, making available a total of \$30 million for research and development work in fiscal year 1967.

The effect of the language adopted by the conference committee is (1) to extend the saline water research and development program for an additional 5 years through fiscal year 1972; (2) to authorize an additional \$15 million to be appropriated for research and development work, which amount, when added to previously authorized but unappropriated funds, makes available \$35 million for appropriation after fiscal year 1966; and (3) to require additional authorization by the Congress for the appropriation of amounts above \$90 million, with such additional amounts limited to \$185 million.

The language recommended by the conference committee is necessary, in our judgment, if the responsibilities of the Congress for this program are to be met. The adoption of this language is not to be interpreted as a lack of confidence in the executive branch. The inclusion of the \$185 million figure indicates approval for planning purposes of the full program recommended by the President.

By its very nature, saline water conversion is a program where it is quite uncertain from one year to the next what direction the research effort is to take. It is understandable that the program presented to the Congress for the 5-year extension was in terms only of the goals which it was hoped might be attained. The prosecution of this program for another five years will involve important policy decisions which cannot be made at this time—decisions which are primarily the responsibility of the Congress.

Under the language adopted by the conference committee, the program for the 5-year period can be planned and formulated as recommended by the President. The \$90 million ceiling on the amount authorized to be appropriated makes available \$35 million or \$6 million more than the preliminary program of the Office of Saline Water for fiscal year 1967. Beginning in fiscal year 1968, it is the position of the conference committee that the research and development work to be accomplished under this program should be approved on a year-by-year basis. Therefore, the Department of the Interior should submit to the Congress at the appropriate time legislation to approve the research and development work proposed to be accomplished in fiscal year 1968.

WAYNE N. ASPINALL,
LEO W. O'BRIEN,
WALTER ROGERS,
JOHN P. SAYLOR,
ED REINECKE,

Managers on the Part of the House.

INTEREST EQUALIZATION TAX

Mr. DELANEY from the Committee on Rules reported the following privileged resolution (H. Res. 468, Rept. No. 719) which was referred to the House calendar and ordered to be printed:

Resolved, That upon the adoption of this resolution it shall be in order to move that the House resolve itself into the Committee of the Whole House on the State of the Union for the consideration of the bill (H.R. 4750) to provide a two-year extension of the interest equalization tax, and for other purposes. After general debate, which shall be confined to the bill and shall continue not to exceed three hours, to be equally divided

and controlled by the chairman and ranking minority member of the Committee on Ways and Means, the bill shall be considered as having been read for amendment. It shall be in order to consider the substitute amendment recommended by the Committee on Ways and Means now in the bill and such substitute shall be considered as having been read for amendment. No other amendment to the bill or committee substitute shall be in order except amendments offered by direction of the Committee on Ways and Means, and said amendments shall be in order, any rule of the House to the contrary notwithstanding, but such amendments shall not be subject to amendment. At the conclusion of such consideration, the Committee shall rise and report the bill to the House, with such amendments as may have been adopted, and the previous question shall be considered as ordered on the bill and amendments thereto to final passage without intervening motion, except one motion to recommit with or without instructions.

INCOME TAX TREATMENT OF CASUALTY LOSSES ATTRIBUTABLE TO MAJOR DISASTERS

Mr. MILLS. Mr. Speaker, I ask unanimous consent for the immediate consideration of the bill (H.R. 7502) relating to the income tax treatment of certain casualty losses attributable to major disasters, which was unanimously reported by the Committee on Ways and Means.

The Clerk read the title of the bill. The SPEAKER. Is there objection to the present consideration of the bill?

Mr. COLLIER. Mr. Speaker, reserving the right to object, and I shall not object, I take this time for the purpose of asking the chairman of the committee to make an explanation of the bill.

Mr. MILLS. Mr. Speaker, will the gentleman yield?

Mr. COLLIER. I am happy to yield to the gentleman.

Mr. MILLS. Mr. Speaker, the purpose of H.R. 7502 as reported to the House by the Committee on Ways and Means is to amend the provisions of existing law relating to the income tax treatment of casualty losses to provide that if property is destroyed or damaged by a storm, flood, or other casualty which is designated by the President of the United States as a major disaster, then, if the losses exceed the gains, both the losses and the gains will be treated as ordinary for tax purposes.

Under present law, uninsured business losses—or those from property held for the production of income—arising from a fire or other casualty are treated as ordinary losses without regard to any gains the taxpayer may have. This rule is not changed by H.R. 7502—which was introduced by our colleague in the Committee on Ways and Means, the gentleman from Oregon, the Honorable AL ULLMAN. In the case of major disasters, the pending bill supplements this rule of existing law to provide substantially similar loss treatment for partially insured business property—or property held for the production of income. This loss treatment also is provided in the case of major disasters for losses of personal assets held for over 6 months—such as a personal residence—whether or not it is covered by any insurance.

In addition, a technical amendment makes it clear that uninsured losses arising from the destruction—in whole or in part—theft, or seizure, or requisition or condemnation of property—used in the trade or business or capital assets held more than 6 months—are to be offset against gains otherwise treated as capital gains except to the extent they are specifically excluded from the provision.

The Treasury Department has indicated that it has no objection to this legislation, and the Committee on Ways and Means is unanimous in urging its enactment.

Mr. COLLIER. Mr. Speaker, I thank the gentleman.

Mr. Speaker, I withdraw my reservation of objection.

The SPEAKER. Is there objection to the present consideration of the bill?

There was no objection.

The Clerk read the bill as follows:

H.R. 7502

A bill relating to the income tax treatment of certain casualty losses attributable to major disaster

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) section 1231(a) of the Internal Revenue Code of 1954 is amended by adding at the end thereof the following new sentence: "In the case of any involuntary conversion of property (subject to the provisions of this subsection but for this sentence) in respect of which the taxpayer is compensated for by insurance in some amount, and which is attributable to a storm, flood, fire, or other casualty which is subsequently designated by the President of the United States as a major disaster for the purposes of the Act of September 30, 1950, as amended, entitled 'An Act to authorize Federal assistance to States and local governments in major disasters, and for other purposes' (64 Stat. 1109), this subsection shall not apply to such involuntary conversion (whether resulting in gain or loss) if, during the taxable year, the recognized losses from such partially insured conversions exceed the recognized gains from such involuntary conversions."

(b) The amendment made by this Act shall apply to taxable years ending after November 30, 1964.

With the following committee amendment:

Strike out all after the enacting clause and insert:

"That (a) section 1231(a) of the Internal Revenue Code of 1954 is amended by adding at the end thereof the following new sentence: 'In the case of any involuntary conversion of property (subject to the provisions of this subsection but for this sentence) which is attributable to a storm, flood, fire, or other casualty designated by the President of the United States as a major disaster for the purposes of the Act of September 30, 1950, as amended, entitled "An Act to authorize Federal assistance to States and local governments in major disasters, and for other purposes" (42 U.S.C., secs. 1855-1855g), this subsection shall not apply to such involuntary conversion (whether resulting in gain or loss) if, during the taxable year, the recognized losses from such conversions exceed the recognized gains from such conversions.'

"(b) The amendment made by subsection (a) shall apply to taxable years ending after November 30, 1964.

"SEC. 2. (a) Paragraph (2) of section 1231 (a) of the Internal Revenue Code of 1954 is amended by inserting after 'losses' the first

SENATE

15. INDEPENDENT OFFICES APPROPRIATION BILL. Both Houses agreed to the conference report on this bill, H. R. 7997. This bill will now be sent to the President. pp. 18752-6, 18880-6
16. LABOR-HEW APPROPRIATION BILL. Passed as reported this bill, H. R. 7765 (pp. 18858-71). Conferees were appointed (p. 18871). House conferees have not yet been appointed. The bill includes funds for air and water pollution control activities by HEW.
17. INTERGOVERNMENTAL COOPERATION; GRANTS-IN-AID. Passed as reported S. 561, the proposed Intergovernmental Cooperation Act of 1965 (pp. 18843-53). Sen. Muskie stated that the bill would: Unify and coordinate the standards and procedures governing the financial, organization, and other activities of the Governors and other State officials, insofar as these activities are affected by Federal grant programs. Provide for systematic review of future Federal grants-in-aid to the States and to local units of government; and stipulates that the Comptroller General shall make continuing studies of all grant programs to assist the Congress in maintaining proper legislative oversight. Permit Federal departments and agencies to provide specialized and technical services to State and local units of government on a reimbursable basis.
18. SALINE-WATER RESEARCH. Both Houses agreed to the conference report on S. 24, to expand, extend, and accelerate the saline water conversion program of the Department of the Interior. This bill will now be sent to the President. pp. 18756-7, 18871-3
19. MILITARY CONSTRUCTION. Agreed to the conference report on H. R. 8439, the military construction bill, which includes an item for payment of CCC for certain family housing which was financed from the sale of surplus commodities. This bill will now be sent to the President. pp. 18854-7
20. OCEANOGRAPHY. Passed as reported S. 944, to provide for expanded research and development in the marine environment of the U. S., to establish a National Council of Marine Resources and Engineering Development, and a Commission on Marine Resources and Engineering Development, and a Commission on Marine Science, Engineering, and Resources. pp. 18829-43
21. STOCKPILING. The Armed Services Committee reported without amendment H. Con. Res. 100, expressing the approval of Congress for the disposal of raw silk and silk noils from the national stockpile (S. Rept. 541). p. 18809
22. DISASTER RELIEF. Sen. Kennedy, N. Y., reviewed and expressed concern over drought conditions in the northeast, urged additional Federal aid for the stricken areas, and stated that he was asking this Department to take the necessary steps to release CCC stored grains as a supplemental feed for cattle. Several Senators commended his statement. pp. 18897-904
23. FOOD MARKETING. Sen. Hart inserted the interim report of the National Commission on Food Marketing reviewing the activities of the Commission to date. pp. 18827-8
24. FOREIGN TRADE. Sen. Javits inserted two items on the progress of current GATT trade negotiations, including comments on the status of negotiations regarding the export of U. S. agricultural products. pp. 18814-9

25. FOREIGN AFFAIRS. Sen. Nelson commended the international farm youth exchange program and the international conference of farm youth to be held next month in Munsingen, Switzerland. pp. 18821-2
26. WILDLIFE. Sen. Metcalf inserted an editorial in support of his bill to forbid removal of land from the National Wildlife Refuge System except with approval of the Migratory Bird Conservation Commission. p. 18825
27. PUBLIC LAW 480. Received from GAO a report on "insufficient amounts claimed" from foreign governments for recovery of ocean transportation costs financed under Public Law 480. p. 18808
28. CLAIMS. Received from this Department the annual report on tort claims. p. 18800
29. CONTRACTS. Received from the Labor Department a proposed bill "to provide labor standards for certain persons employed by Federal contractors to furnish services to Federal agencies"; to Labor and Public Welfare Committee. p. 18809
30. PATENTS. Sen. McClellan announced that the Subcommittee on Patents, Trademark and Copyrights of the Judiciary Committee will hold a hearing Tues., Aug. 17, on bills to establish a uniform Government patent policy. p. 18810

ITEMS IN APPENDIX

31. SOCIAL SECURITY; MEDICARE. Sen. Dirksen inserted two Department of Health, Education, and Welfare publications, "Health Insurance for the Aged--A Brief Explanation of 'Medicare'" pp. A4341-2, and "Social Security Amendments, 1965--A Brief Explanation". pp. A4252-4.
32. DAIRY; BUTTER. Extension of remarks of Rep. Stalbaum endorsing and inserting two resolutions of the Wisconsin Legislature, one urging use of butter in domestic welfare programs, and second requesting Congress to use Wisconsin agricultural products in foreign aid programs. pp. A4348-9
33. LOANS; HOUSING. Extension of remarks of Rep. McGrath commending and inserting an address by FHA Administrator Howard Bertsch at the dedication of a "self-help homes" project in N. J. pp. A4351-2
34. FARM PROGRAM. Extension of remarks of Rep. Ullman urging enactment of the farm bill and inserting a letter supporting this bill. pp. A4360-1
35. WEIGHTS AND MEASURES. Rep. Miller inserted an article urging study of the feasibility and practicality of changing the U. S. system of weights and measures to metric. p. A4362
36. FARM LABOR. Rep. Roosevelt inserted a newspaper article calling for enactment of a minimum wage law for farm workers. pp. A4362-3.

BILLS INTRODUCED

37. PERSONNEL. H. R. 10294 by Rep. Beckworth, to reduce the time in standby status of firefighting personnel of the Federal Government; to Post Office and Civil Service Committee.
H. R. 10298 by Rep. Krebs and H. R. 10299 by Rep. Olsen, Mont., to provide that time spent in actual official travel shall be considered hours of work; to Post Office and Civil Service Committee.

Urban renewal programs, Title I

PROGRAM HIGHLIGHTS

[Dollars in millions]

	Actual, 1964	Estimate, 1965	Estimate, 1966
Net cumulative approvals, year-end:			
Community renewal programs.....	118	138	158
Demonstration grants.....	49	64	79
Urban renewal projects, Total.....	1,466	1,631	1,831
Grant-assisted activities complete.....	157	225	295
Description of project activity—Number of projects active in year:			
Planning.....	782	781	756
Execution.....	769	943	1,075
Code enforcement and rehabilitation.....	139	168	205
Land acquisition.....	472	613	730
Relocation.....	418	560	710
Demolition and removal.....	461	610	745
Project improvements.....	368	430	490
Public facilities.....	228	269	310
Land disposition.....	445	500	555
New construction and redevelopment.....	444	551	633
Localities with projects or CRP's.....	758	816	888
Workable programs for community improvement.....	881	945	1,020
Cumulative authorizations and appropriations:			
Grant contract authority provided.....	\$3,975	\$5,400	\$5,400
Reservations and other utilization.....	3,966	4,631	5,391
Amount appropriated.....	1,065	1,295	1,626
Disbursements.....	1,012	1,291	1,623

Mr. JONAS. Mr. Speaker, the record shows that in addition to the \$94.5 million in new money contained in this bill, the conferees agreed to liquidate \$331 million in contract authorizations heretofore made by the Urban Renewal Administration. It also shows that there is in the pipeline, unspent but reserved and committed, nearly \$3 billion of additional funds which will be available in the future to meet commitments heretofore made.

In addition to this, the new housing bill, which has passed both Houses of Congress but has not been signed into law by the President, will provide an additional \$2.9 billion of future spending authority for the Urban Renewal Administration.

Mr. Speaker, I also ask unanimous consent to include with my remarks the statement of the managers on the part of the House, appearing on page 13 of the report, in discussing amendment No. 87, because I believe the RECORD should contain the statement of the managers with respect to our intention not to cripple or damage this program and our intention to recommend funding in the future on a 2-year basis in order to give the mayors and city councils a sufficient amount of leadtime to make their plans, to have their bond elections, and to make the other commitments they need to make in order to carry on any urban renewal program they may have.

The SPEAKER. Is there objection to the request of the gentleman from North Carolina?

There was no objection.

The statement is as follows:

Amendment No. 87: Restores language proposed by the House with respect to administrative expenses or technical services in connection with contracts for grants for urban renewal. The conferees support the program and recognize its many outstanding benefits. A supplemental request for the balance of fiscal year 1966 as well as the entire fiscal year 1967 is anticipated at an early date at which time 2-year advance funding will be recommended. The conferees are agreed that this leadtime will amply allow for the mechanics of the program and at the same time provide an op-

portunity for the Congress to review this program as is now done with other programs involving planning and financial relations with local communities. The conferees are convinced this agreement will not jeopardize advance planning by local communities and will give them ample opportunity to make plans for the future.

Mr. GROSS. Mr. Speaker, will the gentleman yield?

Mr. JONAS. I yield to the gentleman from Iowa.

Mr. GROSS. I wish to say to my good friend from North Carolina [Mr. JONAS] and to the members of this Appropriations Subcommittee, that it is going to become increasingly difficult to assimilate conference reports on appropriation bills which increase the spending on the part of the Federal Government. I say that because we are going to be confronted in a very short time with a request from the President for an additional \$1.7 billion for the war in Vietnam. I assume that this will be in addition to the \$700 million he requested only a few weeks ago.

It behooves the Members of the House and the Congress to begin to take stock of the fiscal situation of this Government. I believe the House of Representatives was liberal when it passed this bill. It is liberal in the matter of most appropriation bills.

To see conference reports with increased amounts is going to be hard to assimilate in the days to come, if we are going to continue to become engaged in wars and other military actions around the world. It seems to me the time has come for us to stop and take inventory of what we are doing by way of spending the taxpayers' money. Let me hasten to add that what I have said is to be taken as a criticism of this committee to the exclusion of any other. The brakes should have been applied, and long ago, by every committee.

Mr. JONAS. I will say to the gentleman from Iowa that I concur in that view. I do remind the gentleman, however, that I believe it was on yesterday, from his committee, when there came before the House a bill that will cost

about a hundred million a year, although the civil service retirement fund is already \$40 billion in the red.

And that is only one of the new programs authorized by this Congress so far this year. The place to stop the spending is when these new programs and new authorization bills are brought to the floor. I will say to the gentleman from Iowa that this conference report is \$319 million under the budget estimate. We have made other substantial cuts this year in appropriation bills. We cannot, however, close down programs in the Committee on Appropriations. That is not our responsibility. The place to stop the spending is when the authorization bills come to the floor of the House.

Mr. GROSS. Mr. Speaker, will the gentleman yield further?

Mr. JONAS. Yes. I will be glad to yield to the gentleman.

Mr. GROSS. The gentleman has not heard anything yet with respect to bills coming out of committees. Soon he will be confronted with a bill from the Committee on Post Office and Civil Service to increase his pay by subterfuge. The total cost of the proposed pay raise for all Federal employees, excepting Members of Congress, will be in the nature of \$1.6 billion.

Mr. JONAS. I will say in reply to the gentleman from Iowa that if the bill retains that provision increasing the pay of Members of Congress, I will vote against it, as I have on previous occasions. And I have not decided yet whether I will vote for it even if it eliminates the pay increases for Members of Congress.

Mr. EVINS of Tennessee. Mr. Speaker, I yield such time as he may require to the distinguished gentleman from Massachusetts [Mr. BOLAND].

Mr. BOLAND. Mr. Speaker, I want to take this opportunity to compliment the distinguished gentleman from Tennessee who chaired the conferees from the House on this very important bill.

Mr. Speaker, this is the first time in 14 years that our distinguished, brilliant and beloved chairman of the Subcommittee on Appropriations for Independent Offices, the Honorable ALBERT THOMAS, of Texas, has not managed the managers on the part of the House in the conference which the House is now considering. ALBERT THOMAS became chairman of the Subcommittee on Independent Offices of the Committee on Appropriations in 1949. He has occupied that position every year since that time up to the present date, with the exception of the 83d Congress, during the years 1953 and 1954. During all of these years he has never missed a conference on this bill with the Senate conferees. He has always handled the bill when it has emerged from the conference. May I also add, Mr. Speaker, that in the 11 years I have served with him on this subcommittee he rarely missed presiding over the regular hearings—the long and oftentimes laborious hearings—on the regular budget justifications. The tall Texas has been a tenacious champion of the rights of the Congress and the preservation of its

powers. No Member of this House is more admired or respected than the gentleman from Texas. He is in Texas today. We expect him to be back with us soon. I know that the prayers of the Members of this House and of the entire membership ride with him.

We all wish him Godspeed.

Mr. EVINS of Tennessee. Mr. Speaker, I yield such time as he may require to the distinguished majority leader [Mr. ALBERT].

SIGNING OF VOTING RIGHTS BILL BY THE PRESIDENT

Mr. ALBERT. Mr. Speaker, I take this time to advise Members of the House upon the invitation of the Speaker and the majority leader of the Senate the President will sign the voting rights bill tomorrow at noon in the rotunda of the Capitol. All Members of the House are invited by the President and the Speaker to be present at this ceremony.

Mr. KIRWAN. Mr. Speaker, the conference report on H.R. 7997 will be considered and adopted today and the architect of the accomplishment will not be here to receive the recognition and accolades he so justly deserves. Congressman ALBERT THOMAS of Texas, the distinguished chairman of the Subcommittee on Independent Offices Appropriations, has personally handled this bill through every Congress since he became chairman of the subcommittee. He would be here today if it was humanly possible, but doctor's orders forbade any appearance and directed him to a hospital in his beloved Texas.

I came to Congress with this distinguished gentleman in 1936 and have served on the Appropriations Committee with him since 1942. ALBERT THOMAS is one of the finest gentlemen I have ever known, and one of the most dedicated public servants it has been my honor to serve with in the Halls of Congress. He has no peer in his love of this great country of ours and his dedication to duty reflects the fine qualities of a loyal, trusted servant of the people.

Godspeed and best wishes to this distinguished gentleman for a complete and hasty recovery. We miss him and need him in the Congress.

Mr. EVINS of Tennessee. Mr. Speaker, I move the previous question on the conference report.

The previous question was ordered.

The conference report was agreed to.

The SPEAKER. The Clerk will report the first amendment in disagreement.

The Clerk read as follows:

Senate amendment No. 77: Page 22, line 19, strike out "\$20,000,000" and insert "\$18,611,000"

Mr. EVINS of Tennessee. Mr. Speaker, I offer a motion.

The Clerk read as follows:

Mr. EVINS of Tennessee moves that the House recede from its disagreement to the amendment of the Senate numbered 77 and concur therein with an amendment, as follows: In lieu of the sum proposed by said amendment, insert "\$18,629,250".

The motion was agreed to.

The SPEAKER. The Clerk will report the next amendment in disagreement.

The Clerk read as follows:

Senate amendment No. 118: Page 47, line 1: insert:

"DIRECT LOAN REVOLVING FUND"

"The amount authorized by section 1823 (a) of title 38, United States Code, to be advanced after June 30, 1965, by the Secretary of the Treasury to the Administrator, for the purposes of the 'Direct loan revolving fund' is hereby reduced by the amount of \$100,000,000."

Mr. EVINS of Tennessee. Mr. Speaker, I offer a motion.

The Clerk read as follows:

Mr. EVINS of Tennessee moves that the House recede from its disagreement to the amendment of the Senate numbered 118 and concur therein.

The motion was agreed to.

A motion to reconsider the votes by which action was taken on the several motions was laid on the table.

Mr. EVINS of Tennessee. Mr. Speaker, I ask unanimous consent to revise and extend my remarks and to include a summary table of the agencies and amounts in the bill.

The SPEAKER. Without objection, it is so ordered.

ELECTION OF MEMBER TO COMMITTEE

Mr. MILLS. Mr. Speaker, I offer a privileged resolution (H. Res. 502) and ask for its immediate consideration.

The Clerk read as follows:

H. RES. 502

Resolved, That JOSEPH E. KARTH, of Minnesota, be, and he is hereby, elected a member of the Standing Committee of the House of Representatives on Merchant Marine and Fisheries.

The resolution was agreed to.

A motion to reconsider was laid on the table.

SALINE WATER CONVERSION PROGRAM

Mr. ASPINALL. Mr. Speaker, I call up the conference report on the bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, and ask unanimous consent that the statement of the managers on the part of the House be read in lieu of the report.

The Clerk read the title of the bill.

The SPEAKER. Is there objection to the request of the gentleman from Colorado?

There was no objection.

The Clerk read the statement.

(For conference report and statement, see proceedings of the House of August 3, 1965.)

Mr. ASPINALL. Mr. Speaker, I ask unanimous consent that the gentleman from Pennsylvania [Mr. SAYLOR] and I have permission to extend our remarks in the RECORD immediately preceding the adoption of the conference report.

The SPEAKER. Without objection, it is so ordered.

There was no objection.

Mr. ASPINALL. Mr. Speaker, we have been able to resolve the differences be-

tween the House and Senate in S. 24 in a very satisfactory manner. The principal issue was congressional oversight and, therefore, I want to first assure my colleagues that the conference report on S. 24 permits the Congress to meet its responsibilities in the years ahead in connection with the saline water research and development program.

As passed by my committee and by the House, this legislation provided only for the fiscal year 1967 program. While we recognized the need for extending this program, we were convinced that the responsibilities of the Congress could not be met under the language recommended by the administration. The Senate approved the administration bill without change, thereby providing for a 5-year extension in the program and for the authorization of an additional \$200 million to be appropriated for research and development work.

Mr. Speaker, the language adopted by the conference committee will permit this program to go forward as recommended by the President and at the same time provide the opportunity for the Congress to meet its responsibility for reviewing and authorizing the research work. The language of the conference report extends the program for another 5 years through fiscal year 1972. It authorizes an additional \$15 million to be appropriated for research and development work and thereby makes available \$35 million in unappropriated funds. However, it requires additional authorization by the Congress for the appropriation of amounts above the \$35 million. In other words, the program has been extended 5 years as the President recommended and the full amount of an additional \$200 million is recognized as appropriate for planning purposes, and, on the basis of information furnished the committee, more than sufficient funds are authorized to be appropriated for fiscal year 1967.

For the years following fiscal year 1967, it will be necessary for the Congress to authorize the appropriation of additional amounts. It is the position of the conference committee that this should be done on a year-by-year basis—in other words, by an annual authorization bill. There are important decisions to be made in connection with this program that cannot be made at this time. Among other things, they relate to the Federal role and responsibilities in connection with this program and its relationship to our overall national water research effort.

Mr. Speaker, I believe that this conference report provides the basis for an all out effort in saline water conversion. It permits the research and development work to go forward at the pace necessary to attain the goals recommended by the President. I urge its adoption.

Mr. SAYLOR. Mr. Speaker, I agree with the distinguished chairman of the Interior and Insular Affairs Committee that the conference report on S. 24 provides the control which Congress must retain over the saline water conversion program in the years ahead if the Congress is to meet its legislative responsi-

bility. While we have extended the program for another 5 years, and no one ever questioned the need for this time for planning purposes, we have not authorized appropriations beyond fiscal year 1967. Beginning in fiscal year 1968, we expect to authorize the research and development work on a year-by-year basis. In my opinion, this is the only way we can assure a proper Federal role in this program and see that the proposed expenditures are justified.

Mr. Speaker, this program had its beginning in the Congress and in the House Interior and Insular Affairs Committee in 1952; we have maintained close surveillance of the program since that date. We have reviewed the program almost every year and have amended the original act on three different occasions, changing the emphasis and direction as needed. During this period, project administrators have come and gone. The point I am making, Mr. Speaker, is that this is a program originating in the Congress and we are interested in making it a success.

As a result of this report, I sincerely hope the Office of Saline Water will use some truly imaginative research in their efforts to find a method or methods of economically converting saline water and other mineral charged waters so that we can be prepared to meet the ever growing water demands of all sections of this Nation.

I have some reservations about the so-called leap forward in big plant development. This involves the matter of how far the Federal Government should go in assisting development of any particular method or process once it has reached the hardware stage and has been proven effective. We could spend many millions of dollars on large plants which could be made obsolete overnight by new discoveries.

Mr. Speaker, under procedures established in this conference report, I believe that the decisions which are properly the responsibility of the Congress can be made to move this program forward in the best interest of the Nation. I hope that the conference report will be adopted.

Mr. RYAN. Mr. Speaker, I rise in support of the conference report on S. 24 to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior. The conference version of the bill increases from \$10 to \$15 million the additional authorization for fiscal year 1967 provided by this bill for the saline water conversion program.

Our Nation's great cities all face, in the coming decades, an enormous need for water. Population and industry are expanding rapidly, and with them our demand for water is also increasing rapidly.

Many areas of the country are currently suffering from a lack of sufficient water reserves. In New York City, our water storage levels were, as of yesterday, down to 44.6 percent of capacity, or much less than a year's supply. The Federal Water Resources Council pre-

dicts the drought will be even worse next year. Moreover, for the sole purpose of protecting water intakes in the tidal areas of the Delaware from saline water intrusion, New York City must spill 155 million gallons a day into that river from its reservoirs. If this release requirement is continued, four of the city's reservoirs will be dry by November. Other major cities, including Washington, D.C., also have severe drought problems.

In our search for new and economical sources of supply, we must couple sound water management with an aggressive program of technological research. The Federal Water Commission Act—H.R. 10244—which I introduced on August 3, aims at sound water management by treating the allocation and pollution of water resources as related and truly national problems. The desalination program we are voting on today represents a comparable national effort to enlarge the water resources available in our densely populated coastal areas. Both are needed urgently; we can afford neither the luxury of a nonintegrated water use policy nor the false economy of an underfinanced desalination program.

The present bill will increase to \$35 million the amount available to the Department of Interior during fiscal year 1967 for the continuation of its work. This is not enough. We need a far broader and better financed program of basic research and experimental plants if we are to fulfill the hope of a real breakthrough in the cost of desalination.

We know that the cost of desalting water is decreasing steadily. In 1952, when our Federal saline water program was started, the cost was \$5 for every 1,000 gallons. It has been driven down to \$1 for every 1,000 gallons. But it must be cut still further if we are to be able to utilize the desalting process to provide water for our cities.

Mr. Speaker, Kenneth Holum, the Assistant Secretary of the Interior for Water and Power, has called the idea of providing water for our cities through desalination "very complicated and very exciting." It is a vital idea, aimed at one of our Nation's most urgent needs. It deserves proper support. I call upon my colleagues to quickly enact the present bill and help give that support.

The SPEAKER. The question is on the conference report.

The conference report was agreed to.

A motion to reconsider was laid on the table.

TLINGIT AND HAIDA INDIANS OF ALASKA

Mr. ASPINALL. Mr. Speaker, I ask unanimous consent to take from the Speaker's desk the bill (S. 893) to amend the act of June 19, 1935 (49 Stat. 388), as amended, relating to the Tlingit and Haida Indians of Alaska, together with a Senate amendment to the House amendments thereto and concur in the Senate amendment.

The Clerk read the title of the bill.

The Clerk read the Senate amendment, as follows:

Strike out the matter proposed to be inserted by amendment numbered 7 of the House engrossed amendments and insert in lieu thereof the following:

"Sec. 2. As used in the Act of June 19, 1935, as amended by this Act, the terms 'Indians of Tlingit or Haida blood who reside in the various local communities or areas in the United States or Canada' and 'persons of Tlingit or Haida blood who reside in the various local communities or areas in the United States or Canada' mean only persons of Tlingit or Haida blood residing in a local community or area in the United States or Canada who were legal residents of the Territory of Alaska on June 19, 1935, or prior thereto, or who are descendants of persons of Tlingit or Haida blood who were legal residents of the Territory of Alaska on June 19, 1935, or prior thereto."

The SPEAKER. Is there objection to the request of the gentleman from Colorado?

There was no objection.

The Senate amendment to the House amendments was concurred in.

A motion to reconsider was laid on the table.

Mr. ASPINALL. Mr. Speaker, I ask unanimous consent that the gentleman from Pennsylvania [Mr. SAYLOR] and I be permitted to extend our remarks at this point in the RECORD.

The SPEAKER. Without objection, it is so ordered.

There was no objection.

Mr. ASPINALL. Mr. Speaker, the purpose of the Senate amendment to the amendment proposed by the House to section 2 of S. 893 on July 12, 1965, is to clarify and limit the number of Indians of Tlingit and Haida blood who may be eligible to share in the forthcoming judgment. Some of the Tlingit and Haida Indians who were living in Alaska in 1935 have since moved to the other 49 States and Canada. We want to be certain that only those who were actually legal residents of the Territory of Alaska in 1935 or are descendants of persons of Tlingit and Haida blood who were legal residents in 1935 may apply for a share when the award is made. We do not know how many there may be because the tribal rolls have not been completed and the Indians cross into British Columbia with ease. We do not want to prevent any eligible persons from applying for a share. Neither do we want to encourage every Tlingit and Haida Indian living in Canada to think that he may be eligible to share in the award.

The Senate amendment to the House amendment clarifies a possible misunderstanding on the part of the Tlingit and Haida Indians.

[Mr. SAYLOR addressed the House. His remarks will appear hereafter in the Appendix.]

INTEREST EQUALIZATION TAX EXTENSION ACT OF 1965

Mr. DELANEY. Mr. Speaker, by direction of the Committee on Rules I call up House Resolution 498 and ask for its immediate consideration.

The Clerk read the resolution, as follows:

H. RES. 498

Resolved, That upon the adoption of this resolution it shall be in order to move that the House resolve itself into the Committee of the Whole House on the State of the Union for the consideration of the bill (H.R. 4750) to provide a two-year extension of the interest equalization tax, and for other purposes. After general debate, which shall be confined to the bill and shall continue not to exceed three hours, to be equally divided and controlled by the chairman and ranking minority member of the Committee on Ways and Means, the bill shall be considered as having been read for amendment. It shall be in order to consider the substitute amendment recommended by the Committee on Ways and Means now in the bill and such substitute shall be considered as having been read for amendment. No other amendment to the bill or committee substitute shall be in order except amendments offered by direction of the Committee on Ways and Means, and said amendments shall be in order, any rule of the House to the contrary notwithstanding, but such amendments shall not be subject to amendment. At the conclusion of such consideration, the Committee shall rise and report the bill to the House, with such amendments as may have been adopted, and the previous question shall be considered as ordered on the bill and amendments thereto to final passage without intervening motion, except one motion to recommit with or without instructions.

Mr. DELANEY. Mr. Speaker, I yield 30 minutes to the gentleman from California [Mr. SMITH] and pending that I yield myself such time as I may consume.

Mr. Speaker, House Resolution 498 provides for consideration of H.R. 4750, a bill to provide a 2-year extension of the interest equalization tax, and for other purposes. The resolution provides a closed rule with 3 hours of general debate, making it in order to consider the substitute amendment now in the bill.

H.R. 4750, as reported, extends the interest equalization tax from December 31, 1965, to July 31, 1967, or for 1 year and 7 months beyond its present termination date. Thus, this tax, which is designed to aid our balance-of-payments position, will be in effect for a further temporary period. This tax raises the cost to foreigners of obtaining capital in the U.S. capital market to a level more closely aligned with the costs prevailing in capital markets of the other industrialized countries. The present act accomplishes this objective by imposing a tax resulting in an additional annual cost, ultimately borne by the foreign issuers or security holders, equal to approximately a 1-percent rise in interest costs. The tax was first imposed for the period July 19, 1963, through December 31, 1965.

In addition to the extension of the interest equalization tax and its application to debt obligations of 1 to 3 years' maturity, this bill also makes a series of perfecting amendments designed to meet problems which have arisen since the enactment of the tax on September 2, 1964.

Mr. Speaker, I urge the adoption of House Resolution 498.

Mr. SMITH of California. Mr. Speaker, I yield myself such time as I may consume.

(Mr. SMITH of California asked and was given permission to revise and extend his remarks.)

Mr. SMITH of California. Mr. Speaker, as stated by the distinguished gentleman from New York [Mr. DELANEY], the rule does provide for 3 hours of debate under a closed rule insofar as prohibiting any amendments, except those offered by the Committee on Ways and Means, for the consideration of H.R. 4750, the Interest Equalization Tax Extension Act of 1965.

I think, Mr. Speaker, that House Resolution 498, as well as the bill, calls for a 2-year extension. That happens to be the title of the bill. As I understand it, however, the administration did request a 2-year extension, but this extension, according to the committee, was not granted for a period of 2 years but for a period of 1 year and 7 months, from December 31, 1965, to July 31, 1967. So, an amendment, as I understand it, will be offered to correct that.

Mr. Speaker, there are 14 amendments, as set forth on pages 2, 3, and 4 of the report. At that time U.S. balance of international payments has been in a deficit position in every year but once since 1949. These persistent deficits, which have averaged \$2,326 million a year during the period 1950 to 1964, on a regular transaction basis, have led to a significant drain on the U.S. stock of gold, which declined by \$9,082 million between 1950 and 1964.

The enactment of the interest equalization tax, together with other programs undertaken in recent years, for a period substantially reduced the payments deficit. The problem remains serious, however, due in large part to outflows of funds which in the past were not covered by the tax.

There was considerable argument about this bill when it was originally passed. I do not know whether this will solve the problem or not.

Mr. Speaker, I do not know of any opposition to the rule. I therefore urge adoption of the rule.

Mr. Speaker, I yield 3 minutes to the gentleman from Missouri [Mr. CURTIS].

Mr. CURTIS. Mr. Speaker, I am opposed to the rule. I opposed the rule in the committee. This matter should be brought to the floor of the House for debate, but not under a closed rule. This is a closed rule. I see no basis or reason for it. I want to do what I can to keep us from getting into the habit of bringing matters before the House in this fashion. In light of the ruling last week by the Chairman of the Committee of the Whole in respect to amendments to section 14(b) of the Taft-Hartly Act, there is no justification for not permitting the House to work its will on this particular section or this part of the 1954 Tax Code.

This rule goes even further and I call attention to the manner in which we increasingly are depriving ourselves, as Members of the House, of the ability to have meaningful debate. On page 2 of the rule, it states that the Ways and Means Committee, and of course I am a member of that committee, and I do

not want to have this kind of authority put in here that we can offer amendments and "said amendments shall be in order, any rule of the House to the contrary notwithstanding." Frankly, I do not know of any amendments that are subject to a point of order, but I certainly do not think this is good procedure for our committee or any committee unless there is a reason, and that reason should be spelled out by members of the Rules Committee. Certainly I do not know why there should be a special privilege granted for the waiving of the rules of the House by the Committee on Ways and Means. Then there is a phrase, "but such amendments shall not be subject to amendment."

One can easily see from the small attendance on the floor of the House today and the attendance that will exist during the debate in Committee of the Whole, when we debate one of the most serious measures ever facing the Nation today, that no decision is going to be made by Members of the House here in the well of the House. When we take away the power of amendment from the House of Representatives and put it in the position of voting up or down a bill, of course, there can be no meaningful debate. I hope to see the day—and I hope I am here in the House long enough to see it—when there will be meaningful debate in the well of the House on fiscal matters which vitally affect the welfare of our Nation. I have not seen very many, and one reason, the basic reason for this unfortunate situation is this kind of gag rule that we are continually adopting and unnecessarily so.

Mr. FULTON of Pennsylvania. Mr. Speaker, will the gentleman yield?

Mr. CURTIS. I yield to the gentleman from Pennsylvania.

Mr. FULTON of Pennsylvania. I agree with the gentleman in his statement because this closed rule is taking away from the House the power of amendment. It is a severely closed rule, and the more such restrictive rules are used other than when it is absolutely necessary, then the further away from the people our House decisions become. We in Congress should be fair and take time to hear minority views and give opportunity for amendments.

I agree with the gentleman too that there should be a question addressed as to why we have this closed rule and that question should be answered by the committee itself.

Further we should ask the committee: What is the reason for the period time of extension of this tax and why the difference between the two times that have already been mentioned? I think the gentleman has made a good statement and I hope there is a record vote on the rule.

Mr. DELANEY. Mr. Speaker, I have no further requests for time and I move the previous question.

The previous question was ordered. The SPEAKER. The question is on agreeing to the resolution.

The question was taken.

Mr. FULTON of Pennsylvania. Mr. Speaker, I object to the vote on the

is no further amendment to be proposed, the question is on the engrossment of the amendments and the third reading of the bill.

The amendments were ordered to be engrossed, and the bill to be read a third time.

The bill (H.R. 7765) was read the third time and passed.

Mr. HILL. Mr. President, I move that the Senate insist upon its amendments and request a conference with the House of Representatives on the disagreeing votes of the two Houses, and that the Chair appoint the conferees on the part of the Senate.

The PRESIDING OFFICER. The question is on agreeing to the motion of the Senator from Alabama.

The motion was agreed to; and the Presiding Officer appointed Mr. HILL, Mr. STENNIS, Mr. PASTORE, Mr. BIBLE, Mr. BYRD of West Virginia, Mr. COTTON, and Mrs. SMITH conferees on the part of the Senate.

ORDER FOR ADJOURNMENT UNTIL 11:30 A.M. TOMORROW

Mr. MANSFIELD. Mr. President, I ask unanimous consent that when the Senate completes its business today, it stand in adjournment until 11:30 a.m. tomorrow.

The PRESIDING OFFICER. Without objection, it is so ordered.

SIGNING OF THE VOTING RIGHTS BILL IN THE ROTUNDA OF THE CAPITOL

Mr. MANSFIELD. Mr. President, President Johnson is expected to sign the voting rights bill at noon tomorrow in the rotunda of the Capitol. An invitation is extended to all Senators to witness this historic event. Arrangements will be made so that Senators may be absent from the floor at that time in order to participate in the ceremony.

SALINE WATER CONVERSION PRO- GRAM—CONFERENCE REPORT

Mr. MANSFIELD. Mr. President, I submit a report of the committee of conference on the disagreeing votes of the two Houses on the amendment of the House to the bill (S. 24) to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes. I ask unanimous consent for the present consideration of the report.

The PRESIDING OFFICER. The report will be read for the information of the Senate.

The legislative clerk read the report, as follows:

The committee of conference on the disagreeing votes of the two Houses on the amendment of the House to the bill (S. 24) entitled "An act to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes", having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the Senate recede from its disagreement to the amendment of the House and

agree to the same with an amendment as follows: In lieu of the language inserted by paragraph (2) of the House amendment, insert the following:

"(2) In section 8 substitute '\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000,' in lieu of '\$75,000,000 in all,' and substitute '1972' for '1967'."

The PRESIDING OFFICER. Is there objection to the present consideration of the report?

There being no objection, the Senate proceeded to consider the report.

Mr. MANSFIELD. Mr. President, I ask unanimous consent that the conference report, including the statement of the managers on the part of the House, be printed in full at this point in the RECORD.

There being no objection, the report was ordered to be printed in the RECORD, as follows:

CONFERENCE REPORT (H. Rept. No. 720)

The committee of conference on the disagreeing votes of the two Houses on the amendment of the House to the bill (S. 24) entitled "An act to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes", having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the Senate recede from its disagreement to the amendment of the House and agree to the same with an amendment as follows: In lieu of the language inserted by paragraph (2) of the House amendment, insert the following:

"(2) In section 8 substitute '\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000,' in lieu of '\$75,000,000 in all,' and substitute '1972' for '1967'."

And the House agree to the same.

HENRY M. JACKSON,
CLINTON P. ANDERSON,
ALAN BIBLE,
THOMAS H. KUCHEL,
GORDON ALLOTT.

Managers on the Part of the Senate.

WAYNE N. ASPINALL,
LEO W. O'BRIEN,
WALTER ROGERS,
JOHN P. SAYLOR,
ED REINECKE,

Managers on the Part of the House.

STATEMENT

The managers on the part of the House at the conference on the disagreeing votes of the two Houses on the amendment of the House to the bill, S. 24, to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes, submit this statement in explanation of the effect of the language agreed upon and recommended in the accompanying conference report.

Paragraph (2) of the Senate-passed bill reads as follows:

"(2) In section 8 substitute the figure '\$275,000,000' for the figure '\$75,000,000' and the figure '1972' for the figure '1967'."

Paragraph (2) of the House amendment reads as follows:

"(2) In section 8 substitute the figure '\$85,000,000' for the figure '\$75,000,000'."

The conference committee adopted language in lieu of paragraph (2) of the House amendment reading as follows:

"(2) In section 8 substitute '\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000,' in lieu of '\$75,-

000,000 in all,' and substitute '1972' for '1967'."

With the incorporation in the basic act of this language adopted by the conference committee, section 8 will read as follows:

"Sec. 8. There are authorized to be appropriated such sums, to remain available until expended, as may be necessary, but not more than \$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000, (a) to carry out the provisions of this Act during the fiscal years 1962 to 1972, inclusive; (b) to finance, for not more than two years beyond the end of said period, such grants, contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act; and (c) to finance, for not more than three years beyond the end of said period, such activities as are required to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act: *Provided*, That funds available in any one year for research and development may, subject to the approval of the Secretary of State to assure that such activities are consistent with the foreign policy objectives of the United States, be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That every such contract or agreement made with any public or private agency in a foreign country shall contain provisions effective to insure that the results or information developed in connection therewith shall be available without cost to the United States for the use of the United States throughout the world and for the use of the general public within the United States."

Paragraph (2) of the Senate-passed bill would have extended the program for an additional 5 years through fiscal year 1972 and authorized an additional \$200 million to be appropriated for carrying out the research and development work, making available \$220 million for the 6-year period fiscal year 1967-72, inclusive. Paragraph (2) of the House amendment would have authorized only an additional \$10 million to be appropriated for fiscal year 1967, making available a total of \$30 million for research and development work in fiscal year 1967.

The effect of the language adopted by the conference committee is (1) to extend the saline water research and development program for an additional 5 years through fiscal year 1972; (2) to authorize an additional \$15 million to be appropriated for research and development work, which amount, when added to previously authorized but unappropriated funds, makes available \$35 million for appropriation after fiscal year 1966; and (3) to require additional authorization by the Congress for the appropriation of amounts above \$90 million, with such additional amounts limited to \$185 million.

The language recommended by the conference committee is necessary, in our judgment, if the responsibilities of the Congress for this program are to be met. The adoption of this language is not to be interpreted as a lack of confidence in the executive branch. The inclusion of the \$185 million figure indicates approval for planning purposes of the full program recommended by the President.

By its very nature, saline water conversion is a program where it is quite uncertain from one year to the next what direction the research effort is to take. It is understandable that the program presented to the Congress for the 5-year extension was in terms only of the goals which it was hoped might be attained. The prosecution of this program for another 5 years will involve important policy decisions which cannot be made at this time—decisions which are primarily the responsibility of the Congress.

Under the language adopted by the conference committee, the program for the 5-year period can be planned and formulated as recommended by the President. The \$90 million ceiling on the amount authorized to be appropriated makes available \$35 million or \$6 million more than the preliminary program of the Office of Saline Water for fiscal year 1967. Beginning in fiscal year 1968, it is the position of the conference committee that the research and development work to be accomplished under this program should be approved on a year-by-year basis. Therefore, the Department of the Interior should submit to the Congress at the appropriate time legislation to approve the research and development work proposed to be accomplished in fiscal year 1968.

WAYNE N. ASPINALL,

LEO W. O'BRIEN,

WALTER ROGERS,

JOHN P. SAYLOR,

ED REINECKE,

Managers on the Part of the House.

Mr. ANDERSON. Mr. President, the purpose of this legislation is to continue and enlarge the desalination program authorized by the Anderson-Aspinall Act of September 22, 1961, which authorized an expenditure of \$75 million over the 6-year period from 1962 to 1967 inclusive. The President submitted to Congress and the Senate adopted a bill which proposed to increase the authorization by \$200 million and to extend the period of the program by 5 years to 1972. The House version allowed only a \$10-million increase over present authority, and no extension of the period of time. With the \$20 million remaining authorization from the 1961 act, the new authorization provided by the House would have permitted a \$30-million program for fiscal year 1967, but the program would have expired at the end of that year.

The effect of the language adopted by the conference committee is, first, to extend the saline water research and development program for an additional 5 years through fiscal year 1972; second, to authorize an additional \$15 million to be appropriated for research and development work, which amount, when added to previously authorized but unappropriated funds, makes available \$35 million for appropriation after fiscal year 1966; and third, to require additional authorization by Congress for the appropriation of amounts above \$90 million, with such additional amounts limited to \$185 million.

The \$35 million which will be immediately authorized will be adequate for the program planned for fiscal year 1967, and in addition, should provide ample funds necessary for planning for the future of the program.

This will make unnecessary any additional authorization requests under this program, as a practical matter, until fiscal year 1968. Therefore plenty of leadtime is available for the Director of the Office of Saline Water to program his activities.

It was very important to insure a continuation of this program for the 5-year period requested by the President, and I am most gratified that the conference committee agreed to this extension for the following reasons:

First. The 1-year limit on the program would increase the difficulty of planning for future development and

evolution. Many of the processes and principles being developed under this program require a long time for working out the details. Thus, the inability to forecast the amount and availability of additional funds that will be available in succeeding fiscal years may inhibit the development of research contracts and making other arrangements for personnel to carry on the work in the absence of assurance that the program is going to be continued after the 1967 fiscal year.

Second. One of the primary purposes of the saline water conversion program is to evolve processes that can be taken over by industry and developed into commercial applications. Limitation of the Federal program to 1 more fiscal year would have undoubtedly inhibited industry in planning for its future research on these processes, because of the uncertainty of funding for continuing work. The 1-year program might even have kept some firms from entering into new work in this field because of their inability to assure that there would be a continuous funding of work started. This uncertainty has now been removed. The longer term authorization contained in the bill as reported from conference will do a great deal to build up confidence in industry that the Federal Government means to pursue the program to a successful conclusion. This will make it more likely that industry would be willing to put more of its own money into the program to go along with the Federal sponsorship of research, and might attract new companies to enter the field.

Third. A similar effect would be realized on the municipalities and other water users who will be required to invest their own money in studies of potential desalting plans as the program advances. For the Federal Government to indicate that it is interested in this program only on a year-to-year basis might prevent municipalities from starting to put money into the program since most projects will take more than one fiscal year to work out.

Fourth. Congressional reduction of the President's program at this stage could have unfortunate effects on our foreign policy. Because of the statements that have already been made by the President and others, it is extremely important that we pursue this program to the greatest possible degree in order to show that American technology is capable of fulfilling the progress statements made by our President on this subject. Observations made by a task force under Secretary Udall which visited the Soviet Union indicate that that nation may already be ahead of us in making use of desalting for increasing municipal and industrial water supplies.

Fifth. One of the difficult problems in any research program carried on by the Federal Government is in securing and retaining competent personnel to supervise the work. Any indication that the program is on a year-to-year basis might tend to disrupt the recruitment of the additional staff needed by the Office of Saline Water and might cause scientists already employed to seek employment elsewhere.

Mr. President, the Office of Saline Water is now under the directorship of a new man who enjoys unusual confidence among the industry and others involved in saline water conversion.

It has taken a long time to get the momentum of the program to the point where it now appears to be on the verge of producing a satisfactory result. I know President Johnson is highly pleased that the language changes proposed in the basic act now before us clearly indicate an intention to appropriate the full amount requested over the life of the program. The last \$185 million will require additional authorization by Congress upon presentation of a justification by the Department of the Interior, but the officials connected with this program are more than willing to do this.

Thus the President is assured of his program, and Congress is assured of an opportunity to participate more fully in it.

I commend the conferees on the part of the House and Senate for the reasonableness and fairness of attitude. In my opinion this Nation and perhaps many nations will receive benefits as a result of the cooperation shown in the enactment of this bill.

In connection with the conference report on S. 24, the water desalination bill now before the Senate, I ask unanimous consent that an article from a publication entitled "Water Desalination Report," dated August 5, 1965, be inserted at this point in my remarks.

I believe this article accurately points out the kind of cooperation shown by both Houses of Congress and the executive branch in reaching final accord on this important legislation.

There being no objection, the article was ordered to be printed in the RECORD, as follows:

WATER DESALINATION REPORT—CONFEREES AGREE TO EXTEND DESALTING PROGRAM, BUT TIE IT TO YEARLY REVIEWS

Politics is the science of the possible, as Aristotle put it, saying there always exists one King parameter to solve any and every political crisis, no matter how involved, if it only can be found. Both the peripety of entangled political situations and Aristotle's wisdom were never better seen than in conference action on the expanded desalting bill, which netted satisfactory solutions and smiles all around last week for the parties concerned. The King parameter, the touchstone resolving all differences over the legislation between the House and Senate Interior Committees, OSW and the President, turned out to be this language of the conference report: "Substitute '\$90 million plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185 million in all,' and substitute '1972' for '1967.'" Thus, this amendment to section 8 of the basic Saline Water Act gives the House what it wanted and insisted upon chiefly by key House Interior Committee members during the last 3 months' congressional debate over the expanded desalting program, namely assurance that Congress will exercise a watchdog role over U.S. saline water activities via annual authorization of OSW's budgetary requests. The Senate gets what it wanted, primarily the guarantee of a concerted engineering-development program up through fiscal 1972. And OSW and the White House in the approval of a 5-year effort and, in effect, the promise of \$200

million to carry out the program, get what they want—the financial support and the kind of flexibility necessary to plan and carry out research-development for commercial economic desalting plants.

Previously, the bill passed by the House struck out the long-term program and authorized only \$30 million for OSW in fiscal 1967 (WDR, July 29, 1965, 4; July 22, 2). But the conference increased the fiscal 1967 figure to \$35 million. Moreover, in setting \$185 million as a ceiling for appropriations for fiscal year 1968 to 1972 and lifting the \$75 million in past year authorizations through fiscal 1967 to \$90 million, the conferees hiked total authorizations to \$275 million through fiscal 1972. The latter amount is exactly the figure the President had requested from Congress in his desalting message earlier this year.

Di Luzio's victory: Already most Washington sources are giving Frank C. Di Luzio, OSW Director, most of the credit for putting the expanded desalting program over on Capitol Hill. Earlier in the congressional session the House committee was threatening an end of the Federal saline water activity. Committee members admit Di Luzio's convincing testimony during hearings—personal, dynamic, portending economically competitive desalting by the seventies—turned the darkness into day. So, Di Luzio's leadership persuading the committee's assent more than any one thing as to practicability of the 5-year program, softening its opposition to the 5-year program, the conference results followed naturally. Morale on the OSW staff at this moment was never higher.

The conference report is to be filed this week in the House of Representatives and is expected to be voted shortly thereafter. The Senate is expected also to approve the conference action, clearing the bill for the White House, without dissent, probably toward the week's end.

The PRESIDING OFFICER. The question is on agreeing to the conference report.

The report was agreed to.

Mr. MANSFIELD. Mr. President, I ask unanimous consent to reconsider the vote by which the conference report was agreed to.

Mr. BARTLETT. Mr. President; I move to lay that motion on the table.

The PRESIDING OFFICER. Is there objection? The Chair hearing none, it is so ordered.

AMENDMENT OF THE MERCHANT MARINE ACT, 1936

Mr. MANSFIELD. Mr. President, I ask unanimous consent that the Senate proceed to the consideration of Calendar No. 413, H.R. 4346.

The PRESIDING OFFICER. The bill will be stated by title.

The LEGISLATIVE CLERK. A bill (H.R. 4346) to amend section 502 of the Merchant Marine Act, 1936, relating to construction differential subsidies.

The PRESIDING OFFICER. Is there objection to the request of the Senator from Montana?

There being no objection, the Senate proceeded to consider the bill.

Mr. BARTLETT. Mr. President, this bill (H.R. 4346) would extend for 1 additional year the authority of the Secretary of Commerce to pay up to a maximum of 55 percent in the construction differential subsidy payments on merchant vessels and up to 60 percent for the reconstruction of passenger vessels.

The bill was passed by the House on April 26, 1965. The Senate Subcommittee on Merchant Marine and Fisheries held hearings on this bill on May 27 and the full committee ordered it favorably reported. The measure is supported by the Maritime Administration and Department of Commerce.

The Merchant Marine Act, 1936, was designed to assist all segments of the merchant marine including the American shipyards. The 1936 act permits U.S. citizens to apply to the Secretary of Commerce for permission to build in U.S. shipyards merchant vessels with the Government paying the difference between the cost of constructing the vessel in a U.S. shipyard as compared with a foreign shipyard. Without this incentive American operators either would not construct new vessels or would construct them abroad for foreign-flag operation.

The 1936 act placed a limit on the difference between the U.S. shipbuilding cost and foreign costs at 50 percent. In recent years shipbuilding prices in the United States and throughout the world have decreased more rapidly abroad than they have here in the United States. As a result the difference in prices has exceeded the 50 percent level on numerous occasions in the past 5 years. It is anticipated that this may be true for at least 1 more year. The purpose of this legislation is therefore to authorize when appropriate the Secretary of Commerce to pay up to 55 percent as the difference between the United States and foreign shipbuilding costs. Without this legislation the maximum figure would remain at the 50-percent maximum in the present law and would therefore require the Government shipyard subsidy to be paid by operators building new merchant vessels or the result would be that American vessel operators in the foreign trade would not construct new merchant vessels. In my opinion, either is unacceptable and I would therefore hope that this legislation would be speedily enacted.

Mr. SALTONSTALL. Mr. President, I wish to ask the Senator from Alaska a question. The bill would continue the maritime construction program for another year at the rate of 55 percent.

Mr. BARTLETT. The Senator from Massachusetts is correct. The program would be extended for 1 year only, as was the case for last year.

Mr. SALTONSTALL. We hope that it will stimulate construction in the maritime field.

Mr. BARTLETT. We constantly hope that it will; and to a very great extent it has.

Mr. WILLIAMS of Delaware. Mr. President, will the Senator yield?

Mr. BARTLETT. I am glad to yield.
Mr. WILLIAMS of Delaware. When was the first change from 50 percent to 55 percent made?

Mr. BARTLETT. In 1960.

Mr. WILLIAMS of Delaware. At that time it was for a 1-year or a 2-year program?

Mr. BARTLETT. Two years at the outset.

Mr. WILLIAMS of Delaware. Then this proposal is the second or third extension?

Mr. BARTLETT. Yes. This is the third extension.

Mr. WILLIAMS of Delaware. Is it the plan of the committee to have a similar extension annually, or has the committee given consideration to a permanent solution of the problem?

Mr. BARTLETT. The committee has given serious and constant attention to the problem. I do not know that I can definitively answer the Senator except by saying that the Maritime Administration and the Department of Commerce, on instructions from President Johnson, as incorporated in his state of the Union message this year, are now engaged in a continuing study, and it is hoped that as a consequence, by next year there will be certain recommendations in that field as well as others to be made to the Congress. The Maritime Advisory Board, made up of public members, labor members, and industry members, meets every month. The next meeting will be tomorrow, with subcommittees from the group in constant session.

Out of all this, we expect some definite recommendations to issue. But the problem, as the Senator knows, is not easy of solution. We can only hope.

Mr. WILLIAMS of Delaware. I recognize that a problem exists in this area; but we were already paying up to 50 percent of the cost of the construction of these ships. The subsidy rate was raised to 55 percent about 5 years ago. Congress decided that for a temporary period up to 55 percent would be allowed with the understanding that at the end of that time a report would be made by the Commission as to exactly how much more would be necessary.

This is now the third extension. If we continue to extend it year after year, I am wondering if soon they will not want more than 55 percent. Certainly they would prefer a 55 percent subsidy to 50 percent. I suppose that next they will want 60 or 65 percent.

Mr. BARTLETT. The operators do not care. The subsidy does not go to the operators; the subsidy goes to the shipyards, it having been determined that when the Government gives help of this kind, the vessel or vessels must be built in American shipyards. So no benefit accrues to the ship operator.

Furthermore, although the American merchant fleet does not carry as much in American exports and imports as the Senator from Delaware and I, and many others, would desire, this particular segment of the program has been quite successful. This subsidy, which allows for the construction of ships in American yards, has gone almost exclusively to the so-called liner fleet. This is one segment of the American merchant marine which has held its own, or approximately so, in the face of fierce foreign competition. The other elements of the fleet—the bulk cargo fleet, for example—have been hard put to it and have not actually succeeded in meeting the foreign competition.

But this particular part of the American merchant marine fleet that will be helped by the taxpayers through this construction subsidy and operating sub-

sidy is in good shape. The United States has the most modern vessels in the world in its liner cargo fleet.

Mr. WILLIAMS of Delaware. What the Senator from Alaska says is encouraging; but are not many of the ships tied up now in port because of a strike so that they cannot operate? That may not be as a result of this bill; nevertheless, they have an excellent chance to remain in good condition since they are tied up and foreign ships are being used for transportation. American tourist business is being lost, perhaps never to be recovered.

Mr. BARTLETT. Oh, yes; we know that a strike has been in progress for a long time; but, as the Senator correctly says, that has no relation to the pending bill.

Mr. WILLIAMS of Delaware. It has no relation to the pending bill except that it relates to another problem which has been receiving study by the Department and by Congress over the past several years. Apparently all that is done is to study; nobody graduates. I am wondering if there should not be an examination of the study groups someday to see if they have learned anything. If they have not perhaps they should be given an accelerated course in one of the many new programs of this Great Society.

I am wondering if it is not time that someone suggested that after spending all the money for studies we should determine an answer. As long as they can get a free ride at the taxpayers' expense we shall never get a report.

Mr. BARTLETT. I do not recall that any degrees have been awarded to anyone with respect to maritime disputes, which is another subject. But I insist, to the extent of my ability, that the bill before us now, the bill we are considering, the bill unanimously passed by the House of Representatives, is a useful legislative accomplishment, because it will keep this particular element of the American merchant fleet viable and modern, and will enable it to retain a far greater share of our export-import cargo business than the bulk cargo fleet handles.

Mr. WILLIAMS of Delaware. Based upon the committee reports, I understand that over the years this particular maritime subsidy has cost the United States \$740 million. The net effect is that we are paying up to 55 percent of the construction cost of these ships. After construction, we are paying a subsidy to keep them operating on the high seas.

I come back to my original question: Is it not time that the committee insisted on having the study groups make recommendations? Perhaps Congress should serve notice that if they do not come forward with a solution we shall let one the programs lapse.

Mr. BARTLETT. I do not believe it would be fair for us to do that. I have had something to do with the American merchant marine since I came to the Senate. I would dislike to have someone give me an injunction tomorrow to submit next week or next month some relevant recommendations.

The subject is extremely complex. Yes; we have spent hundreds of millions of dollars on the program. But we have done so out of a calculated belief that subsidies are essential, first, to maintain, in being, American shipyards, and this is partly—largely, perhaps—for the national defense. We have done it partly to enable our ships to sail the high seas, after they have been constructed, in competition with foreign flag carriers, whose operating costs are much lower.

If the U.S. Government did not pay differential subsidies, if it did not pay operating subsidies, we would not have any liner fleet at all. At a minimum, we would have a liner fleet no more consequential in terms of carrying American cargo than the cargo fleet; and that fleet carries only 5 percent of American cargoes.

It is incumbent upon us to turn to the other part of the merchant marine and try to shore it up in some manner or other, so that our whole fleet will be strengthened.

Mr. WILLIAMS of Delaware. I recognize that considering the different labor standards and the cost of materials in this country as compared with foreign countries there must be a subsidy of some kind if ships are to be constructed in American shipyards, but there is a question as to the extent to which such a subsidy should be paid. With such high rates we have destroyed the incentive for efficiency. The committee recognized that in the 1936 act, but soon the percentage of subsidy had been extended all the way to 50 percent. Then, 5 years ago, on a strictly temporary basis, Congress extended the rate up to 55 percent for the period of 2 years or until a report and study could be obtained from the Department.

No report has been forthcoming, and this is the third extension. While I shall not attempt any organized objection to the bill at this time I shall not support it. Nevertheless, I believe we should serve notice now on the Department that if it has not submitted the result of the work of the study group by next year and it asks for another extension, it may be in trouble. We shall at least expect it to change the pupils in the class.

Mr. BARTLETT. I am sure that the officials in the executive department will hear what the Senator has said.

I should add, finally, that we are not extending the program from year to year only awaiting recommendations from the executive branch. We are extending the program because 55 percent is the closest figure the executive branch can arrive at to represent the difference between the cost of building ships in foreign shipyards and building them in American shipyards.

Mr. WILLIAMS of Delaware. That is true, but when the 55 percent proposal was made 5 years ago, the Department admitted that the figure was pulled out of thin air, that the actual rate would have been closer to 52 or 53 percent. Now the percentage has reached 55 percent, and soon they will be asking for 60 percent unless they are checked.

I return to the question of study groups. Apparently all that they did

was to pull a figure out of thin air, but they cannot determine whether it is justified or not.

I still believe it is time they submitted some solid recommendations. In the absence of a solid report perhaps Congress should submit some kind of recommendation. Let us see if we cannot pull a lower figure out of thin air for them by this time next year.

Mr. BARTLETT. The figures are incorporated in the report. They show that the smallest differential was 55.2 percent, but that most of the differential was from 53.9 percent to 54 percent and over 54 percent.

Mr. WILLIAMS of Delaware. They are approaching the 55 percent ceiling. When they hit that they will come out of the thin air again with another figure, perhaps 60 percent, and justify it on the basis that they will continue to study it.

There is a limit as to what we can expect the taxpayers to underwrite as to the construction cost of these ships and at the same time have them operated as a segment of our private enterprise system.

Mr. BARTLETT. There are some other solid reasons why we should look forward to a diminishment of this differential rather than an increase. Whether it will come into being next year, I am not prepared to say. However, the wages being paid in the European and the Japanese shipyards are rising much faster than are the wages being paid in our own shipyards.

There is every reason to expect that, relatively soon, we shall be able to lower this construction differential subsidy. I hope so as ardently as does the Senator from Delaware.

Mr. WILLIAMS of Delaware. I join the Senator in expressing the hope that that is true; however, we find all too often that when the wage rates have increased in other countries the high subsidies continue. I shall not belabor the subject any longer, but this should be sufficient warning to the group.

I know that the Senator from Alaska is trying to do the best job that he can, but I hope that he will join me in seeing that the Department will come forward with a better recommendation next year.

Mr. BARTLETT. I always will.

Mr. President, I ask unanimous consent that the individual views of the Senator from Ohio [Mr. LAUSCHE] as printed in the Senate report No. 428, be printed at this point in the RECORD.

There being no objection, the individual views were ordered to be printed in the RECORD, as follows:

INDIVIDUAL VIEWS OF MR. LAUSCHE

We are again confronted with an administration request to extend the annual \$100 million shipbuilding subsidy for another year which renews the limit of 55 percent for the construction of new merchant ships and a 60-percent limit for the reconversion of certain passenger vessels. This subsidy represents the difference between the world market price and the price of constructing the same ship in American shipyards.

The current subsidy program of cost parity was provided by the Merchant Marine Act of 1936 in order to maintain an efficient, sound, and competitive merchant marine.



Public Law 89-118
89th Congress, S. 24
August 11, 1965

An Act

79 STAT. 509.

To expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to expand, extend, and accelerate the saline water conversion program conducted by the Secretary of the Interior, the Act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951 et seq.), is hereby further amended as follows:

Saline water
conversion pro-
gram.
75 Stat. 628.

(1) In section 2(b) add the words “, module, component,” after the word “laboratory”.

(2) In section 8 substitute “\$90,000,000, plus such additional sums as the Congress may hereafter authorize and appropriate but not to exceed \$185,000,000,” in lieu of “\$75,000,000 in all,” and substitute “1972” for “1967”.

Approved August 11, 1965.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 594 accompanying H. R. 7092 (Comm. on Interior & Insular Affairs) and No. 720 (Comm. of Conference).

SENATE REPORT No. 319 (Comm. on Interior & Insular Affairs).

CONGRESSIONAL RECORD, Vol. 111 (1965):

June 16: Considered and passed Senate.

July 12: Considered and passed House, amended, in lieu of H. R. 7092.

Aug. 5: House and Senate agreed to conference report.

